

Mill Creek

Sediment TMDL for a Benthic Impairment Shenandoah County, Virginia



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CHAPTER 1: EXECUTIVE SUMMARY

1.1. Background

A part of the North Fork Shenandoah River basin, the Mill Creek watershed (Watershed ID VAV-B48R_MIL01A00) is an upstream portion of state hydrologic unit B48, and is located in Shenandoah County, Virginia as shown in Figure 1.1. The watershed is 29,753 acres in size. The land use in Mill Creek is mainly forest (53%) and pasture (44%), with a small amount of cropland (2%) and urban and residential land uses (1%). Mill Creek flows east and discharges into the North Fork of the Shenandoah River, which flows into the Shenandoah River, which flows into the Potomac River; the Potomac River discharges into the Chesapeake Bay.

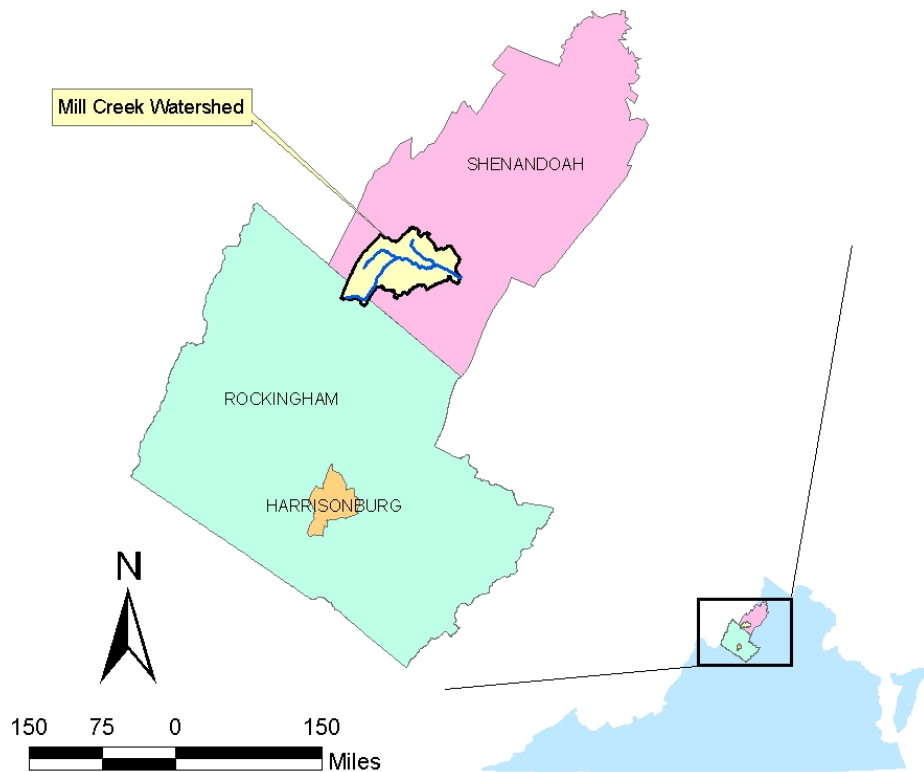


Figure 1.1. Location of Mill Creek Watershed

1.2. Benthic Impairment

1.2.1. Background

Mill Creek was originally listed as impaired on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report due to water quality violations of the general aquatic life (benthic) standard. As a result, the Environmental Protection Agency (EPA) added this stream to a 1998 consent order requiring a TMDL by 2010. In 2002, a bacterial impairment on Mill Creek was also added to the Section 303(d) list (VADEQ, 2002a).

The Virginia Department of Environmental Quality (VADEQ) has delineated the benthic impairment on Mill Creek (stream segment VAV-B48R-01) as a stream length of 7.6 miles. The impaired stream segment begins at the confluence of Mill Creek and Straight Run and ends at the confluence of Mill Creek with the North Fork of the Shenandoah River. Crooked Run is a named tributary that flows into the impaired segment of Mill Creek around stream mile 2.90.

1.2.2. Benthic Stressor Analysis

TMDLs must be developed for a specific pollutant. Since a benthic impairment is based on a biological inventory, rather than on physical and chemical water quality parameters, the pollutant is not implicitly identified in the assessment, as it is with physical and chemical parameters. The process outlined in the United States Environmental Protection Agency's (USEPA) Stressor Identification Guidance Document (USEPA, 2000) was used to identify the critical stressor for Mill Creek.

The possible stressors to Mill Creek are nutrients, organic matter, and sediment, with no dominant source. Minor improvements appear to have been made in organics-related metrics based on the fixed Stream Condition Index (SCI), rather than the relative Rapid Bioassessment Protocol (RBP), scoring thresholds. Livestock access to streams and lack of riparian vegetative cover appear to be the major sources of stress on the benthic community in Mill Creek. Ambient and biological monitoring data indicate that the impact from the Mill

Creek watershed above station MIL005.67 is minor. The problem appears to be localized to segments of Mill Creek downstream from station MIL005.67 near its confluence with Crooked Run, segments of Crooked Run, and in one unnamed tributary. Since Crooked Run had very poor biological metric scores and enters Mill Creek only 0.7 miles above the listing benthic station (MIL002.20), it appears to exert a major influence on samples at the listing station. After discussion with the regional DEQ TMDL coordinator and biologist, and state DEQ and DCR personnel, sediment was selected as the most probable stressor in Mill Creek.

Since many best management practices (BMPs) employed to control sediment result in decreases in the other possible stressors (i.e., nutrients and organics) as well, and since a staged implementation approach is being used to address benthic impairments in Virginia, the choice of sediment was judged to be the most logical. The ultimate criteria for judging the success of the TMDL will be the restoration of the benthic community itself.

1.2.3. Sources of Sediment

Sediment is generated in the Mill Creek watershed through the processes of surface runoff, streambank and channel erosion, as well as from background geologic forces. Natural sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, and urban land uses. In Mill Creek, these activities relate primarily to livestock access to streams and lack of riparian vegetation. Animals grazing on pastures in riparian areas with access to streams tend to detach sediment through hoof action and generally contribute to the instability of streambanks in those areas.

1.2.4. Modeling

The TMDL to address the benthic impairment in Mill Creek was developed using sediment as the pollutant. Because Virginia has no numeric in-stream criteria for sediment, a “reference watershed” approach was used to set allowable loading rates in the impaired watershed. The reference watershed approach pairs two watersheds: one whose streams are supportive of their designated uses, and one whose streams are impaired. The non-impaired upper portion of

Mill Creek watershed (above station MIL005.67) was selected as the TMDL reference watershed for the Mill Creek watershed. The proximity of the watershed was the primary basis for selection of this watershed. The similarities of land use (though of slightly different proportions) should provide target loads appropriate for the downstream impaired segment.

The Generalized Watershed Loading Function (GWLF) model (Haith et al., 1992) was selected for comparative modeling of both the impaired and TMDL reference watersheds in this TMDL study. Channel erosion was modeled explicitly within GWLF using the algorithms included in the AVGWLF adaptation of the GWLF model (Evans et al., 2001) in a modified version of GWLF that corrects for a flow accumulation coding error.

1.2.5. Margin of Safety

The margin of safety (MOS) was explicitly modeled as 10% of the calculated TMDL to reflect the relative degree of accuracy expected from paired watershed modeling with GWLF.

1.2.6. Benthic TMDL for Sediment

The TMDL to address the benthic impairment in Mill Creek was developed using sediment as the pollutant and the upper portion of Mill Creek watershed as the TMDL reference watershed. The land area in the upper Mill Creek watershed (6,150.4 ha) is less than the land area in the overall Mill Creek watershed (12,041.0 ha). In order to establish a common basis for comparing loads between these two watersheds, each land use category in the upper Mill Creek watershed was proportionally increased to create an area-adjusted upper Mill Creek watershed, equal in size with the overall Mill Creek watershed, while maintaining its original land use distribution. TMDL modeling was then performed on the equal-area watersheds to generate sediment loads for comparison using a common 8-yr period of weather inputs (April 1997 - March 2005) as representative of the normal expected range of local weather conditions. The sediment loads for existing conditions were modeled for each

watershed and are listed in Table 1.1 by land use category both as annual average loads (t/yr) and as unit-area loads (t/ha) for individual land uses.

Table 1.1 Existing Sediment Loads

| Sediment Sources | Mill Creek | | Area-adjusted Mill Creek 5.67 | |
|------------------------------------|-------------------|---------------|--|---------------|
| | (t/yr) | (t/ha) | (t/yr) | (t/ha) |
| High Till | 2,335.7 | 13.84 | 708.6 | 14.67 |
| Low Till | 557.7 | 5.53 | 171.8 | 5.95 |
| Pasture | 2,523.4 | 0.71 | 719.3 | 0.50 |
| Hay | 858.0 | 0.51 | 251.8 | 0.37 |
| Forest | 403.0 | 0.06 | 241.5 | 0.02 |
| Transitional | 598.5 | 38.07 | 382.1 | 13.69 |
| Pervious Urban | 15.1 | 0.13 | 4.7 | 0.12 |
| Impervious Urban | 15.6 | 0.41 | 1.2 | 0.22 |
| Channel Erosion | 71.8 | | 41.0 | |
| Permitted Point Sources | 0.9 | | 0.4 | |
| Watershed Totals | 7,379.8 | | 2,522.5 | |
| Target Sediment TMDL Load = | | | 2,522.5 | t/yr |

The sediment TMDL for Mill Creek is comprised of three required components - WLA, LA, and MOS - as quantified in Table 1.2. The average annual sediment load in metric tons per year (t/yr) from the area-adjusted upper Mill Creek watershed (from Table 1.1) was used to define the TMDL sediment load for Mill Creek. The margin of safety (MOS) was explicitly specified as 10% of the calculated TMDL. The waste load allocation (WLA) was included as the contribution from the one permitted industrial stormwater facility and eight 1,000-gpd housing units covered under the general permit. And finally, the load allocation (LA) - the allowable sediment load from nonpoint sources - was calculated as the TMDL minus the MOS minus the WLA.

Table 1.2. Mill Creek Sediment TMDL (t/yr)

| TMDL (t/yr) | WLA (t/yr) | LA (t/yr) | MOS (t/yr) |
|------------------------|--|----------------------|-----------------------|
| 2,522.5 | 0.9 | 2,269.3 | 252.2 |
| | VAR050943 Hepner Blocks: 0.6 8 - 1000gpd General Permits: 0.3 | | |

1.2.7. TMDL Reductions and Allocations

Changes in future land use distribution and sediment sources were judged to be minimal, and were modeled as constant. The TMDL allocations, therefore, were based on existing land uses and sediment sources.

For development of the allocation scenarios, overland non-point sediment sources were grouped into the following three categories: Agriculture, Residential/Urban, and Forestry. Additionally, Channel Erosion and Point Sources were listed as separate categories. Three alternative allocation scenarios were developed to reduce existing sediment loads in Mill Creek to the levels required by the TMDL, as illustrated in Table 1.3. Note that the allocation target load = TMDL - MOS.

Table 1.3. Alternative Load Reduction Scenarios

| Source Category | Reference Mill Creek (t/yr) | Mill Creek Sediment Load | | | | | | |
|-------------------|-----------------------------|--------------------------|----------------------------------|----------------|----------------------------------|----------------|----------------------------------|----------------|
| | | Existing (t/yr) | TMDL Alternative 1 (% reduction) | (t/yr) | TMDL Alternative 2 (% reduction) | (t/yr) | TMDL Alternative 3 (% reduction) | (t/yr) |
| Agriculture | 1,851.5 | 6,274.9 | 81% | 1,165.3 | 73% | 1,678.7 | 69% | 1,929.8 |
| Residential/Urban | 388.0 | 629.2 | 0% | 629.2 | 73% | 168.3 | 69% | 193.5 |
| Forestry | 241.5 | 403.0 | 0% | 403.0 | 0% | 403.0 | 69% | 123.9 |
| Channel Erosion | 41.0 | 71.8 | 0% | 71.8 | 73% | 19.2 | 69% | 22.1 |
| Point Sources | 0.4 | 0.9 | | 0.9 | | 0.9 | | 0.9 |
| Total | 2,522.5 | 7,379.8 | | 2,270.2 | | 2,270.2 | | 2,270.2 |

The sediment TMDL for Mill Creek is 2,522.5 t/yr, but the modeling target is the TMDL minus the MOS (2,270.2 t/yr) and will require an overall reduction of 69% from existing loads. From the three alternative scenarios explored, Alternative 2 is recommended as the most reasonable approach as it requires equal % reductions from all categories except forestry which already produces very low unit-area loads and Point Sources which are permitted.

A concurrent bacteria TMDL for Mill Creek (Benham et al., 2006) requires an increased level of Livestock Exclusion from streams that directly affects the sediment loads from channel erosion in Mill Creek. A coordinated effort to restore the riparian vegetation in conjunction with Livestock Exclusion from localized, targeted stream sections should be a major step in remedying the fairly minor benthic impairment in the Mill Creek watershed.

The Mill Creek sediment TMDL was developed to meet the sediment load of the area-adjusted TMDL reference watershed - upper Mill Creek above station MIL05.67. The TMDL was developed to take into account all sediment sources in the watershed from both point and nonpoint sources. The sediment loads were averaged over an 8-year period to take into account both wet and dry periods in the hydrologic cycle, and the model inputs took into consideration seasonal variations and critical conditions related to sediment loading. An explicit 10% margin of safety was added into the final TMDL load calculation.

1.3. Reasonable Assurance of Implementation

1.3.1. Follow-Up Monitoring

VADEQ will continue monitoring Mill Creek at its established historical station (1BMIL002.20) in accordance with its ambient and biological monitoring programs. It is also recommended that monitoring continue at the MIL005.67 and CKD000.38 stations to further document distribution of impacts on the benthic community for use in focusing implementation efforts during implementation planning. VADEQ will use data from the 1BMIL002.20 monitoring station to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

1.3.2. Regulatory Framework

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairment on Mill Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and

wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

1.3.3. Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation

Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

1.4. Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. The first public meeting was held on May 18, 2005 at St. Andrews Episcopal Church in Mt. Jackson, Virginia to inform the stakeholders of the TMDL development process. Copies of the presentation materials were available for public distribution at the meeting. Approximately 20 people attended the meeting. Two meetings of the Mill Creek Local Steering Committee (LSC) were held to assist with TMDL development. The first LSC meeting was held on November 9, 2005 at the Mt. Jackson Visitor Center/Town Office in Mt. Jackson, Virginia where the results of the benthic stressor analysis were presented and discussed. The second LSC meeting was held on February 21, 2006 at the Edinburg Town Hall in Edinburg, Virginia and addressed issues related both to the benthic impairment for Mill Creek described in this report and a bacteria impairment in Mill Creek and surrounding portions of the North Fork Shenandoah River which are described in a separate report. The draft report from the benthic TMDL study was presented and discussed. Approximately 12 people attended the first LSC meeting. The final public meeting will be held on March 21, 2006 at the Shenandoah County Parks and Recreation Office in Edinburg, Virginia. The public comment period will end on April 20, 2006. A summary of comments received during the comment period and responses to those comments will be documented and will be available through the VADEQ Valley Regional Office in Harrisonburg, Virginia.

CHAPTER 2: INTRODUCTION

2.1. Background

2.1.1. TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

2.1.2. Impairment Listing

Mill Creek was originally listed as impaired on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report due to water quality violations of the general aquatic life (benthic) standard. As a result, the Environmental Protection Agency (EPA) added this stream to a 1998 consent order requiring a TMDL by 2010. In 2002, a bacterial impairment on Mill Creek was also added to the Section 303(d) list (VADEQ, 2002a).

The Virginia Department of Environmental Quality (VADEQ) has delineated the benthic impairment on Mill Creek (stream segment VAV-B48R-01) as a stream length of 7.6 miles. The impaired stream segment begins at the confluence of Mill Creek and Straight Run and ends at the confluence of Mill Creek with the North Fork of the Shenandoah River. Crooked Run is a named tributary that flows into the impaired segment of Mill Creek around stream mile MIL002.90.

2.1.3. Watershed Location and Description

A part of the North Fork Shenandoah River basin, the Mill Creek watershed (Watershed ID VAV-B48R_MIL01A00) is an upstream portion of state hydrologic unit B48, and is located in Shenandoah County, Virginia. The watershed is 29,753 acres (12,041 ha) in size. Mill Creek is mainly a forested watershed (approximately 52%) and is characterized by a rolling valley with the Blue Ridge Mountains to the east and the Appalachian Mountains to the west (Figure 2.1). Nearly forty-four percent of the land is pasture, while two percent is cropland and the remaining one percent is urban and residential. Mill Creek flows east and discharges into the North Fork of the Shenandoah River, which flows into the Shenandoah River, which flows into the Potomac River; the Potomac River discharges into the Chesapeake Bay.

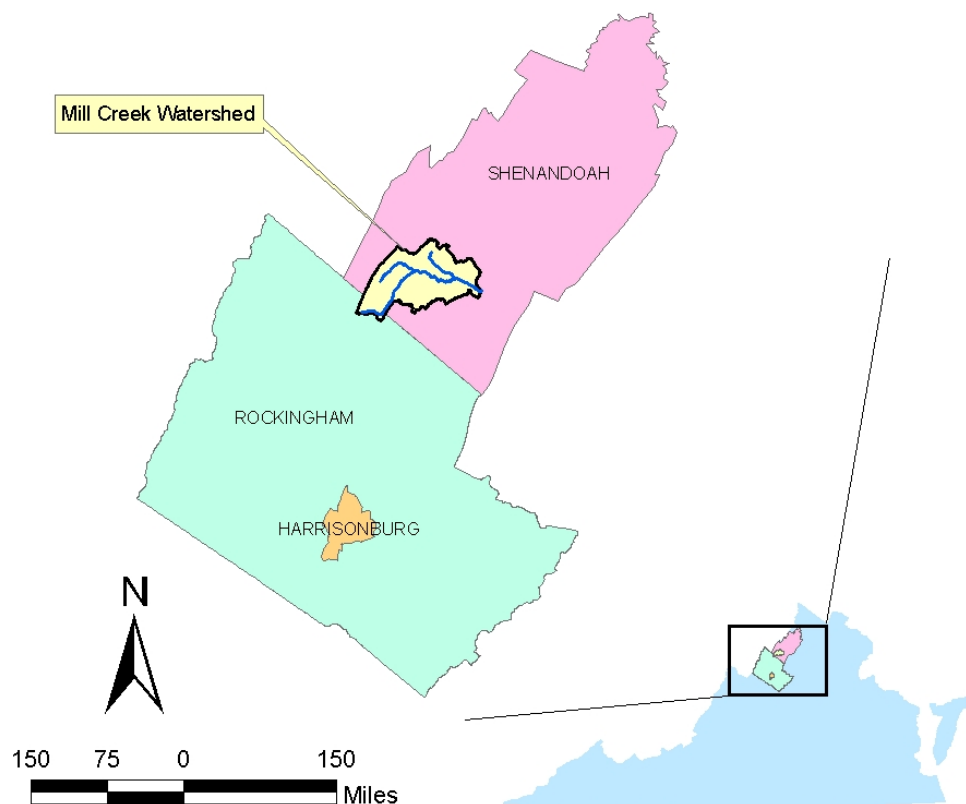


Figure 2.1. Location of Mill Creek watershed

2.1.4. Pollutants of Concern

Pollution from both point and nonpoint sources can lead to a violation of the general standard for water quality. A violation of this standard is assessed on the basis of measurements of the benthic macroinvertebrate community in the stream, with pollution impacts referred to as a benthic impairment. Water bodies having a benthic impairment are not fully supportive of the aquatic life designated use for Virginia's waters.

2.2. Designated Uses and Applicable Water Quality Standards

2.2.1. Designation of Uses (9 VAC 25-260-10)

"A. All state waters are designated for the following uses: recreational uses (e.g. swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)." SWCB, 2002.

2.2.2. General Standard (9 VAC 25-260-20)

The general standard for a water body in Virginia is stated as follows:

"A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.

Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled." SWCB, 2002.

The biological monitoring program in Virginia that is used to evaluate compliance with the above standard is run by the Virginia Department of Environmental Quality (DEQ). Evaluations of monitoring data from this program focus on the benthic (bottom-dwelling) macro (large enough to see) invertebrates (insects, mollusks, crustaceans, and annelid worms) and are used to determine whether or not a stream segment has a benthic impairment. Changes in water quality generally result in alterations to the quantity and diversity of the benthic

organisms that live in streams and other water bodies. Besides being the major intermediate constituent of the aquatic food chain, benthic macroinvertebrates are "living recorders" of past and present water quality conditions. This is due to their relative immobility and their variable resistance to the diverse contaminants that are introduced into streams. The community structure of these organisms provides the basis for the biological analysis of water quality. Qualitative and semi-quantitative biological monitoring have been conducted by DEQ since the early 1970's. The US EPA Rapid Bioassessment Protocol (RBP) II was employed beginning in the fall of 1990 to utilize standardized and repeatable methodology. For any single sample, the RBP produces water quality ratings of "non-impaired," "slightly impaired," "moderately impaired," or "severely impaired." In Virginia, benthic samples are typically taken and analyzed twice a year in the spring and in the fall.

The RBP II procedure evaluates the benthic macroinvertebrate community by comparing ambient monitoring "network" stations to "reference" sites. A reference site is one that has been determined to be representative of a natural, nonimpaired water body. The RBP II evaluation also accounts for the natural variation noted in streams in different ecoregions. One additional product of the RBP evaluation is a habitat assessment. This is a stand alone assessment that describes bank condition and other stream and riparian corridor characteristics and serves as a measure of habitat suitability for the benthic community.

Determination of the degree of support for the aquatic life designated use is based on biological monitoring data and the best professional judgment of the regional biologist, relying primarily on the most recent data collected during the current 5-year assessment period. In Virginia, any stream segment with an overall rating of "moderately impaired" or "severely impaired" is placed on the state's 303(d) list of impaired streams (VADEQ, 2002).

CHAPTER 3: WATERSHED CHARACTERIZATION

3.1. Water Resources

The main branch of Mill Creek runs for 14.99 miles from the headwaters until it enters the North Fork of the Shenandoah River. Straight Run is a major tributary to Mill Creek, and enters Mill Creek about 7.60 miles upstream from its confluence with the North Fork of the Shenandoah River. Another major tributary to Mill Creek is Crooked Run which enters Mill Creek about 2.90 miles upstream from the confluence of Mill Creek with the North Fork of the Shenandoah River.

3.2. Ecoregion

The Mill Creek watershed is located entirely within Level III Ecoregion 67, which is the Central Appalachian Ridge and Valley region, and is located primarily within the Northern Limestone/Dolomite Valleys and the Northern Shale Valleys Level IV Ecoregions. There is also a very small section located in the southwest corner that is classified as the Northern Sandstone Ridges Level IV Ecoregion. The Ridge and Valley Ecoregion is characterized by its generation from a variety of geological materials. The Level III Ecoregion has numerous springs and caves. The ridges tend to be forested, while limestone valleys are composed of rich agricultural land (USEPA, 2002). The Northern Limestone/Dolomite Valleys Level IV ecoregion has fertile land and is primarily agricultural. Steeper areas have scattered forests composed mainly of oak trees. Streams tend to flow year-round and have gentle slopes (Woods et al., 1999). The Northern Shale Valleys Level IV ecoregion is used mainly for farming with woodlands occurring on the steeper slopes. The Northern Sandstone Ridges Level IV ecoregion is characterized by wooded ridges and extensive forest cover.

3.3. Soils and Geology

The main general soil map unit found in the Mill Creek watershed is the Frederick series. Frederick soils (generally silty loam) are deep and well drained.

These soil types are typically found on ridgetops and sideslopes. Other soils found in significant portions of the Mill Creek watershed are the Berks series and the Weikert series (USDA-NRCS, 1991).

3.4. *Climate*

The climate data used in the modeling of the watershed are based on the meteorological observations made by the National Weather Service station (NCDC Coop ID: 442663) in Edinburg, Virginia. The station is located north of the watershed and 7.7 miles (12.5 km) from the DEQ monitoring station MIL002.20. Average annual precipitation at the Edinburgh station is 35.7 inches with 59.8% of the precipitation occurring during the crop-growing season (May-October). Average annual daily temperature is 52.7°F. The highest average daily temperature of 72.7°F occurs in July while the lowest average daily temperature of 32.1°F occurs in January.

3.5. *Land Use*

Land use for the Mill Creek watershed was derived from the National Land Cover Dataset (NLCD). These data are available from the United States Geological Survey (USGS) and are based on early-1990's data from the Landsat Thematic Mapper satellite data. Based on a categorization of the 21 land uses in the NLCD data, the main land use category in Mill Creek is forest, comprising approximately 52% of the total watershed area. Pasture, cropland, and urban/residential acreage accounts for about 43%, 2%, and 1% of the watershed area, respectively, as shown in Figure 3.1.

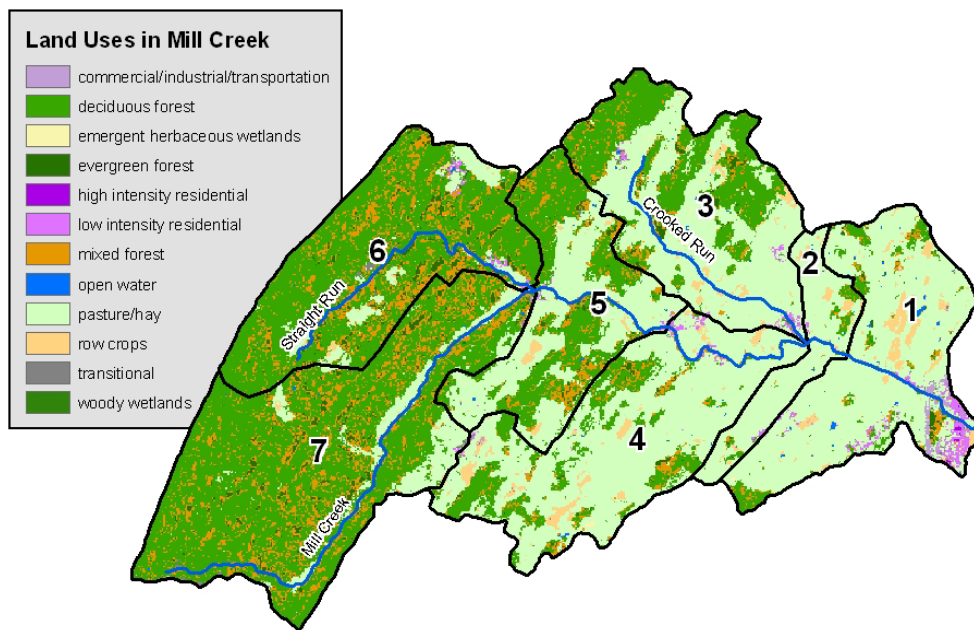


Figure 3.1. Land Use in Mill Creek Watershed

3.6. Stream Flow Data

There were two USGS peak flow gage stations in the watershed. Both stations were located on Crooked Run, which is tributary to Mill Creek. Station 01632950 was located near Conicville, Virginia and recorded peak flow data for the years from 1966 to 1975. The other peak flow monitoring station (01632970) located near Mount Jackson, Virginia recorded peak flow data from 1972 to 2004. No daily flow stations were located on Mill Creek.

3.7. Water Quality Data

The Virginia DEQ (VADEQ) monitored Mill Creek chemical and bacterial water quality on a monthly basis from July 1991 through September 2005 at station MIL002.20. There are also data for station MIL005.67 from July 2001 to May 2003 and for station SRT000.10 from July 2001 to September 2005, all collected on a monthly basis. SRT000.10 is located on Straight Run, a tributary to Mill Creek. These data are described in more detail under the Stressor Analysis discussion. There were four benthic monitoring stations in the watershed. The main benthic station was located at MIL002.20 and has ten years of biological

monitoring data. Two other stations on Mill Creek - MIL005.67 and MIL007.79 - and one station on the Crooked Run tributary (CKD000.38) have each only been sampled once in May 2005. The locations of these DEQ ambient and biological stations are shown in Figure 3.2.

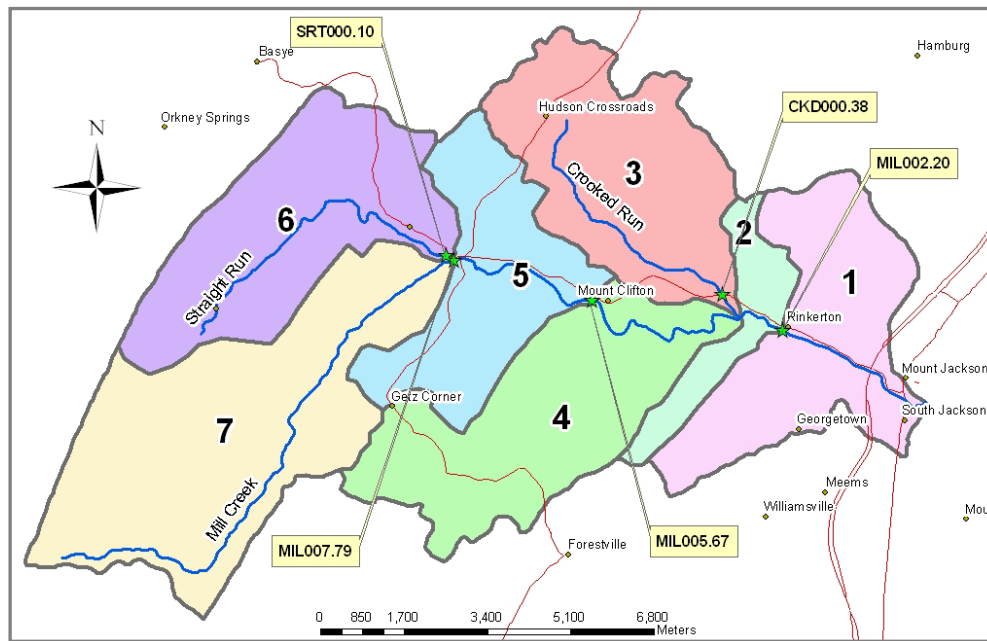


Figure 3.2. Locations of DEQ Monitoring Stations in Mill Creek Watershed

3.7.1. Historic Data – Benthic Macroinvertebrates

Biological communities were monitored on Mill Creek at MIL002.20 annually or semi-annually from Fall 1995 through the Spring of 2005. Additional benthic samples were collected in the Spring of 2005 at three other upstream locations in the watershed: MIL005.67, MIL007.79, and CKD000.38. A full listing of species distribution for each sample is included in Table 3.1. The plaintiffs in Virginia’s consent decree placed the 7.6-mile Mill Creek stream segment on the 303(d) list in 1998 for a benthic impairment. Station MIL002.20 reported the following 305(b) assessments for 1998, 2000, 2002, and 2004 respectively: moderately impaired, slightly impaired, slightly impaired, and moderately impaired. Mistakenly, the 2002 Impaired Waters Fact Sheet lists this station as being “fully supportive” (non-impaired). During all four assessment periods at least two “moderately impaired” ratings were given to consecutive samples,

Table 3.1. Mill Creek Benthic Species Distribution by Sample Date

| FinalID | TolVal | FFG | Habit | MIL002.20 Sampling Dates | | | | | | | | | | | | | | Total Taxa | MIL005.67 | MIL007.79 | CKD000.38 | |
|-------------------|--------|-----------|-------|--------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|------------|-----------|-----------|-----------|----------|
| | | | | 10/25/95 | 05/21/96 | 10/15/96 | 05/27/97 | 09/23/97 | 10/20/98 | 05/18/99 | 11/02/00 | 09/27/01 | 09/27/01 | 05/14/02 | 11/17/03 | 05/20/04 | 09/23/04 | | | | | 05/06/05 |
| Glossosomatidae | 0 | Scraper | cli | | | | 2 | | | | | | | | | | | 2 | | | | |
| Leuctridae | 0 | | | | | | | | | | | | | | | | | 0 | 2 | | | |
| Rhyacophilidae | 0 | Predator | cli | | | | | | 1 | | | | | | | | | 1 | | | | |
| Brachycentridae | 1 | Filterer | cli | | | | | | | | 16 | | | | | | | 16 | | | | |
| Capniidae | 1 | Shredder | | | | | | | | | | | | 1 | | | | 1 | | | | |
| Gomphidae | 1 | Predator | bur | | | | | 1 | | | | | 1 | | | 1 | | 3 | | 1 | | |
| Lepidostomatidae | 1 | Shredder | spr | | | | | | | | | | | 1 | | | | 1 | | | | |
| Perlidae | 1 | Predator | cli | | | | 3 | | | | | | | | | | | 3 | 3 | | | |
| Athericidae | 2 | Predator | spr | | | | | 1 | | | | | | | | | | 1 | | | | |
| Isonychiidae | 2 | Filterer | swi | 2 | 1 | 6 | 3 | 6 | | | 10 | 10 | 6 | 2 | 4 | 1 | 5 | 56 | 1 | 2 | | |
| Leptophlebiidae | 2 | Collector | swi | 1 | 8 | | | | | | | | | | | | | 9 | | | 4 | |
| Nemouridae | 2 | | | | | | | | | | | | | | | | | 0 | | 1 | | |
| Perlodidae | 2 | | | | | | | | | | | | | | | | | 0 | | 2 | | |
| Spongillidae | 2 | | | | | | | | | | | | | | | | | 0 | | | | |
| Taeniopterygidae | 2 | Shredder | spr | | | | | | | | | | | | 1 | | | 1 | | | | |
| Aeshnidae | 3 | Predator | clm | | | 1 | | | | | | | | | | | | 1 | | | | |
| Helicopsychidae | 3 | Shredder | cli | 2 | | | | | | 1 | 8 | 5 | 2 | | | | | 18 | 3 | 1 | | |
| Philopotamidae | 3 | Collector | cli | 28 | | 3 | | 21 | 12 | 6 | 20 | 48 | 53 | 6 | 14 | | 34 | 4 | 249 | | 2 | |
| Tipulidae | 3 | Shredder | bur | | | 1 | | 10 | 2 | | | | | 1 | | 3 | | 17 | 2 | | | |
| Uenoidae | 3 | | | | | | | | | | | | | | | | | 0 | | | | |
| Baetidae | 4 | Collector | swi | | 13 | 7 | 10 | 3 | 3 | 2 | 3 | 10 | 5 | 44 | | 24 | 2 | 17 | 143 | 7 | 17 | 3 |
| Caenidae | 4 | Collector | spr | 1 | | | | | 4 | | 2 | 2 | 5 | 1 | 2 | | | 17 | 1 | | | |
| Elmidae | 4 | Scraper | cli | 12 | 3 | 2 | 8 | 2 | 6 | 19 | 51 | 1 | 4 | 11 | 25 | 7 | 6 | 12 | 169 | 1 | 1 | 25 |
| Ephemerellidae | 4 | Collector | cli | | 8 | | 5 | | 8 | 57 | 88 | 8 | 6 | 50 | 37 | 53 | 21 | 21 | 362 | 44 | 18 | 2 |
| Ephemeridae | 4 | Collector | bur | | | | 2 | | | 1 | | | | | | | | 3 | | | | |
| Heptageniidae | 4 | Scraper | cli | 22 | 6 | 13 | 6 | 3 | 23 | 5 | 32 | 33 | 21 | 16 | 18 | 3 | 16 | 6 | 223 | 8 | 9 | 1 |
| Leptoceridae | 4 | Collector | | 2 | | | | | | 1 | 1 | | | | | | | 4 | | | | |
| Pleuroceridae | 4 | Scraper | cli | 1 | | | 1 | 3 | 2 | 1 | 42 | 5 | 6 | 1 | 7 | 2 | 2 | | 73 | | | |
| Psephenidae | 4 | Scraper | cli | 1 | | 2 | 2 | 1 | 3 | 7 | 9 | 2 | 3 | 6 | 3 | 1 | 5 | 3 | 48 | 3 | 6 | |
| Tricorythidae | 4 | Collector | spr | 1 | | 5 | | | | | 1 | 1 | | 2 | | | 1 | | 11 | | | |
| Calopterygidae | 5 | Predator | clm | 2 | | | | | | | | | | | | | | 2 | | | | |
| Cambaridae | 5 | Shredder | | 1 | | 2 | 1 | 2 | | | | 1 | | | | | | 7 | | | | |
| Corixidae | 5 | Predator | swi | 1 | | | | | | | | | | | | | | 1 | | | | |
| Corydalidae | 5 | Predator | cli | 1 | | | | 1 | | | | | | | | | | 2 | | | | |
| Hydrachnidae | 5 | Predator | | 2 | 1 | 1 | 1 | 1 | | | | | | | | 1 | | 7 | | | | |
| Hydrophilidae | 5 | Predator | | | | | | | | | | | | | 1 | | | 1 | | | | |
| Pyrilidae | 5 | Shredder | clm | | | | | | | 1 | | 3 | 1 | | 1 | | | 6 | | | | |
| Chironomidae (A) | 6 | Collector | | 4 | 83 | 30 | 44 | 10 | 26 | 37 | 62 | 90 | 51 | 90 | 14 | 25 | 3 | 40 | 609 | 26 | 44 | 70 |
| Empididae | 6 | Predator | spr | | | | | | | 2 | 1 | 1 | | 2 | | | | 6 | | 2 | | |
| Gammaridae | 6 | Collector | swi | 2 | | | | | | | | | | | | | | 2 | | | | |
| Hydropsychidae | 6 | Filterer | cli | 27 | 5 | 13 | 25 | 39 | 53 | 17 | 4 | 83 | 40 | 31 | 30 | 7 | 7 | 1 | 382 | 4 | 2 | 4 |
| Hydroptilidae | 6 | Scraper | cli | | | | | | | 2 | 12 | | 1 | | | | | 15 | | | | |
| Polycentropodidae | 6 | Filterer | cli | 1 | | | | | | | 1 | 1 | | | | | | 3 | | 1 | | |
| Simuliidae | 6 | Filterer | cli | | 12 | 8 | 9 | 3 | 1 | 1 | | 1 | 3 | 2 | 5 | | | 45 | | | | |
| Asellidae | 8 | Collector | spr | 2 | | | | | | | | | | | | | | 2 | | | 3 | |
| Corbiculidae | 8 | Filterer | spr | | | | | | | 1 | | | | | | | | 1 | | | | |
| Dendrocoelidae | 8 | | | | | | | | | | | | | | | | | 0 | | | | |
| Gerridae | 8 | Predator | ska | | | | | 1 | | | | | | | | | | 1 | | | | |
| Lumbriculidae | 8 | Collector | | 1 | 3 | 2 | 2 | | | 1 | 1 | | | 1 | | | | 11 | | | | |
| Naididae | 8 | | | | | | | | | | | | | | | | | 0 | | | 1 | |
| Planariidae | 8 | Collector | | 4 | | 2 | 2 | 3 | 4 | | 44 | 4 | 13 | 4 | 2 | | 6 | 1 | 89 | | 1 | |
| Sphaeriidae | 8 | Filterer | spr | | | | | | | | 3 | | 1 | | | | | 4 | | | | |
| Chironomidae (B) | 9 | Collector | bur | | 4 | 2 | | | | | | | | | | | | 6 | | | | |
| Coenagrionidae | 9 | Predator | clm | 2 | | | | | 1 | 1 | 1 | | 1 | 1 | | | | 7 | | | | |
| Sample Abundance | | | | 123 | 147 | 100 | 126 | 115 | 145 | 165 | 412 | 312 | 219 | 273 | 163 | 128 | 108 | 105 | | 105 | 110 | 113 |

- dominant 2 organisms in each sample.

Habit Codes: bur = burrowers;
cli = clingers;
clm = climbers;

ska = skaters;
spr = sprawlers;
swi = swimmers.

except during the 2004 assessment period, when only one sample received a “moderately impaired” rating. Mill Creek watershed was, therefore, retained on the 303(d) list and a TMDL is required for this moderate to slight impairment.

The Rapid Bioassessment Protocol II (RBP II) is the official protocol used to assess compliance with the general standard in Virginia. The RBP II procedure evaluates the benthic macroinvertebrate community by comparing individual network biomonitoring stations with reference biomonitoring stations on reference streams. Reference biomonitoring stations have been identified by regional biologists that are both representative of regional physiographic and ecological conditions and have a healthy, nonimpaired benthic community. A number of different reference stations have been used for Mill Creek over time including Strait Creek (STC004.27), Bullpasture Creek (BLP000.79), Jackson River (JKS067.00), and most recently, Cowpasture River (CWP050.66), as shown in Table 3.2.

Table 3.2. RBP II Scores for Mill Creek (Scored relative to a reference)

| RBP II Metric | 10/25/95 | 05/21/96 | 10/15/96 | 05/27/97 | 09/23/97 | | 10/20/98 | 05/18/99 | | 11/02/00 | | 09/27/01 | 05/14/02 | | 11/17/03 | 05/20/04 | 09/23/04 | 05/06/05 |
|----------------------------|----------|----------|----------|----------|----------|--|----------|----------|--|----------|--|----------|----------|--|----------|----------|----------|----------|
| Taxa Richness | 24 | 11 | 17 | 17 | 19 | | 14 | 20 | | 22 | | 19 | 19 | | 15 | 12 | 12 | 9 |
| MFBI | 4.61 | 5.39 | 5.15 | 5.21 | 4.67 | | 5.12 | 4.76 | | 4.63 | | 4.89 | 4.96 | | 4.50 | 4.45 | 4.00 | 4.78 |
| SC/CF | 0.45 | 0.33 | 0.50 | 0.30 | 0.10 | | 0.42 | 0.56 | | 2.39 | | 0.31 | 0.56 | | 0.53 | 1.63 | 2.42 | 21.00 |
| EPT/Chi Abund | 17.40 | 0.47 | 1.42 | 1.24 | 6.91 | | 3.70 | 2.47 | | 3.14 | | 2.42 | 1.71 | | 7.50 | 3.52 | 28.67 | 1.23 |
| % Dominant | 22.76 | 59.18 | 30.00 | 34.92 | 33.91 | | 36.55 | 34.55 | | 21.36 | | 26.52 | 32.97 | | 22.70 | 41.41 | 31.48 | 38.10 |
| EPT Index | 10 | 6 | 6 | 8 | 6 | | 6 | 10 | | 13 | | 10 | 9 | | 7 | 5 | 7 | 5 |
| Comm. Loss Index | 0.42 | 1.73 | 0.24 | 0.71 | 0.53 | | 0.64 | 0.40 | | 0.18 | | 0.21 | 0.26 | | 0.27 | 0.25 | 0.42 | 0.44 |
| SH/Tot | 0.00 | 0.00 | 0.01 | 0.00 | 0.09 | | 0.01 | 0.01 | | 0.04 | | 0.01 | 0.01 | | 0.02 | 0.02 | 0.00 | 0.00 |
| Biological Condition Score | 32 | 12 | 26 | 20 | 20 | | 18 | 30 | | 38 | | 34 | 32 | | 42 | 38 | 38 | 32 |
| % of Reference | 69.57 | 25.00 | 59.09 | 41.67 | 41.67 | | 39.13 | 65.22 | | 90.48 | | 85.00 | 76.19 | | 95.45 | 82.61 | 82.61 | 69.57 |
| Assessment* | SI | MI | SI | MI | MI | | MI | SI | | NI | | NI | SI | | NI | SI | SI | SI |
| Biological Reference** | STC | STC | STC | BLP | JKS | | STC | STC | | CWP | | CWP | CWP | | CWP | CWP | CWP | CWP |

* NI = Non-Impaired; SI = Slightly Impaired; MI = Moderately Impaired; I = Severely Impaired.

** STC = Strait Creek (STC004.27); BLP = Bullpasture Creek (BLP00.79); JKS = Jackson River (JKS067.00); CWP = Cowpasture River (CWP050.66)

The Macroinvertebrate Aggregated Index for Streams (MAIS) is a secondary index whose metrics are also calculated by VADEQ, but is only used as a supplemental indicator of stream quality. The MAIS metrics were developed using data from the Central Appalachian Ridge and Valley ecoregion, and, as such, are appropriate for use with Mill Creek watershed. Individual MAIS metrics are rated against a fixed scale rather than against those of a reference watershed, as in the RBP II index. The various metrics, some which duplicate

those in the RBP II, along with their scores and final ratings are given for each sample in Table 3.3.

Table 3.3. MAIS Assessments for Mill Creek (Scored against a fixed scale)

| StationID | 1BMIL002.20 | | | | | | | | | | | | | | 1BMIL005.67 | 1BMIL007.79 | 1BCKD000.38 | Best Scores |
|------------------------------|-------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-------------|-------------|-------------|-------------|
| Collection Date | 10/25/95 | 05/21/96 | 10/15/96 | 05/27/97 | 09/23/97 | 10/20/98 | 05/18/99 | 11/02/00 | 09/27/01 | 05/14/02 | 11/17/03 | 05/20/04 | 09/23/04 | 05/06/05 | 05/06/05 | | | |
| Simpsons Diversity Index | 0.86 | 0.66 | 0.86 | 0.82 | 0.84 | 0.80 | 0.81 | 0.88 | 0.83 | 0.82 | 0.87 | 0.75 | 0.83 | 0.78 | 0.76 | 0.78 | 0.57 | ≥ 0.83 |
| No. of Intolerant Taxa | 16 | 7 | 11 | 12 | 14 | 9 | 12 | 13 | 12.5 | 12 | 11 | 10 | 9 | 6 | 11 | 11 | 5 | ≥ 10 |
| % Scrapers | 29.3 | 6.1 | 17.0 | 15.1 | 7.8 | 23.4 | 20.6 | 35.4 | 14.6 | 12.5 | 32.5 | 10.2 | 26.9 | 1.0 | 1.0 | 1.0 | 1.0 | ≥ 11 |
| Dominant 5% | 78.9 | 84.4 | 71.0 | 76.2 | 74.8 | 84.1 | 83.0 | 69.7 | 84.5 | 84.6 | 84.7 | 90.6 | 83.3 | 91.4 | 84.8 | 85.5 | 96.5 | ≤ 79 |
| Modified Family Biotic Index | 4.63 | 5.46 | 5.14 | 5.20 | 4.66 | 5.12 | 4.76 | 4.63 | 4.89 | 4.96 | 4.50 | 4.45 | 4.00 | 4.78 | 4.34 | 4.78 | 5.38 | ≤ 4.21 |
| No. of EPT Taxa | 10 | 6 | 6 | 8 | 6 | 6 | 10 | 13 | 9.5 | 9 | 7 | 5 | 7 | 5 | 9 | 10 | 5 | ≥ 8 |
| No. of Mayfly Taxa | 5 | 5 | 4 | 5 | 4 | 3 | 5 | 6 | 5.5 | 6 | 3 | 4 | 5 | 3 | 5 | 4 | 4 | ≥ 4 |
| % Mayfly Taxa | 22.0 | 24.5 | 31.0 | 20.6 | 13.9 | 23.4 | 40.6 | 33.0 | 19.6 | 42.5 | 36.2 | 63.3 | 41.7 | 41.9 | 58.1 | 41.8 | 8.8 | ≥ 18 |
| % Haptobenthos | 84.6 | 38.1 | 54.0 | 58.7 | 72.2 | 77.9 | 74.5 | 72.6 | 68.5 | 63.4 | 89.6 | 76.6 | 90.7 | 44.8 | 62.9 | 38.2 | 28.3 | ≥ 84 |
| Biological Condition | 17 | 10 | 15 | 15 | 13 | 11 | 14 | 16 | 14 | 14 | 14 | 12 | 15 | 10 | 14 | 13 | 9 | 18 |
| Assessment* | N | M | S | S | S | M | S | S | S | S | S | M | S | M | S | S | M | N |

* N = Non-impaired; S = Slight Impairment; M = Moderate Impairment

A qualitative analysis of various habitat parameters was conducted in conjunction with each biological sampling event. Each of the 10 parameters listed in Table 3.4 were graded on a scale of 0-20, with a maximum score of 20 indicating the most desirable condition, and a score of 0 indicating the poorest habitat conditions. The best possible overall score for a single evaluation is 200.

Table 3.4. Habitat Evaluation Scores for Mill Creek

| Habitat Metrics | MIL002.20 | | | | | | | | | | | | | | MIL005.67 | MIL007.79 | CKD000.38 |
|----------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| | 10/25/95 | 5/21/96 | 10/15/96 | 5/27/97 | 9/23/97 | 10/20/98 | 5/18/99 | 11/2/00 | 9/27/01 | 5/14/02 | 11/17/03 | 5/20/04 | 9/23/04 | 5/6/05 | 5/6/05 | | |
| Channel Alteration | 18 | 18 | 14 | 10 | 18 | 15 | 17 | 18 | 18 | 19 | 20 | 20 | 18 | 18 | 18 | 17 | 12 |
| Bank Stability | 16 | 16 | 16 | 16 | 16 | 20 | 18 | 17 | 18 | 20 | 16 | 20 | 18 | 18 | 16 | 14 | 18 |
| Bank Vegetation | 18 | 16 | 16 | 18 | 14 | 17 | 18 | 18 | 19 | 19 | 18 | 20 | 18 | 18 | 16 | 16 | 18 |
| Embeddedness | 14 | 12 | 16 | 10 | 12 | 16 | 14 | 11 | 11 | 12 | 13 | 18 | 15 | 17 | 18 | 16 | 6 |
| Channel Flow Status | 20 | 20 | 20 | 20 | 18 | 17 | 18 | 17 | 13 | 16 | 17 | 20 | 16 | 18 | 18 | 16 | 17 |
| Riffle Stability | 14 | 16 | 18 | 18 | 18 | 20 | 20 | 19 | 19 | 19 | 20 | 19 | 18 | 19 | 17 | 18 | 17 |
| Riparian Vegetation | 10 | 10 | 10 | 10 | 12 | 6 | 5 | 12 | 15 | 19 | 12 | 10 | 9 | 13 | 7 | 11 | 7 |
| Sediment Deposition | 16 | 14 | 16 | 12 | 14 | 17 | 15 | 17 | 13 | 12 | 15 | 17 | 13 | 17 | 17 | 15 | 6 |
| Substrate Availability | 14 | 14 | 14 | 14 | 14 | 15 | 14 | 16 | 16 | 17 | 15 | 17 | 17 | 17 | 14 | 16 | 13 |
| Velocity/Depth Regime | 18 | 16 | 16 | 18 | 16 | 10 | 13 | 14 | 10 | 15 | 16 | 18 | 16 | 17 | 15 | 14 | 13 |
| Total Habitat Score | 158 | 152 | 156 | 146 | 152 | 153 | 152 | 159 | 152 | 168 | 162 | 179 | 158 | 172 | 156 | 153 | 127 |

RBP Habitat Evaluation Ratings

(Bank Stability, Bank Vegetation, Riparian Vegetation): Poor 0-4; Marginal 6-10; Sub-optimal 12-16; Optimal 18-20.

(All others): Poor 0-5; Marginal 6-10; Sub-optimal 11-15; Optimal 16-20.

10 - Poor or Marginal habitat metrics.

Additional habitat data were available from citizen monitoring data from 1997, 1999, and 2000, as shown in Table 3.5. These data indicate “Stream Quality” that is spatially variable. The poorer habitat areas according to these data were both upstream, headwater areas and areas near the watershed outlet. The data indicate nutrient enrichment in many areas as shown by the high “%algae cover”, as well as some streambank erosion (“SB erosion”).

Table 3.5. Mill Creek Citizen Monitoring Data

| SOS Station | BS-11 | BS-1 | | | BS-3A (BS-9) | | | BS-4 | BS-5A | BS-5 | BS-6 | | BS-7 |
|-----------------------|----------|----------|----------|---------|--------------|-----------|-----------|---------|-----------|---------|----------|-----------|---------|
| Sub-Watershed | MIL1 | MIL1 | | | MIL4 | | | MIL4 | MIL5 | | MIL7 | | MIL6 |
| Date | 11/19/99 | 10/26/99 | 11/20/99 | 5/31/00 | 5/08/97 | 12/1/99 | 4/9/00 | 6/10/00 | 12/17/99 | 6/10/00 | 10/28/99 | 6/14/00 | 6/10/00 |
| Stream Quality Score | | | | 22 | | | 33 | 19 | | 16 | | 10 | 16 |
| Stream Quality Rating | Poor | Good | Good | Good | Excellent | Excellent | Excellent | Good | Excellent | Fair | Fair | Poor | Fair |
| % algae cover | | 50 | 80 | | 20 | 5 | 15 | 100 | 1 | 100 | 30 | | 100 |
| Stream channel shade | 90 | 50 | 60 | 90 | | | | | 10 | | 80 | | |
| SB erosion | 10 | 5 | 5 | 0 | 20 | 10 | 10 | 10 | 10 | 10 | 10 | 0 | 10 |
| % mud | 0 | 0 | 5 | 0 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | | 0 |
| %sand | 0 | 10 | 10 | 5 | 25 | 25 | 25 | 5 | 0 | 5 | 0 | | 0 |
| %gravel | 0 | 20 | 20 | 15 | 30 | 30 | 30 | 25 | 30 | 25 | 10 | | 25 |
| %cobbles | 100 | 60 | 60 | 70 | 30 | 35 | 30 | 75 | 60 | 75 | 50 | | 50 |
| %boulders | 0 | 10 | 5 | 15 | 0 | 0 | 5 | 20 | 10 | 20 | 40 | | 25 |
| Flow rate | | normal | normal | normal | normal | low | low | low | normal | low | normal | high-norm | low |

Virginia DEQ, with assistance from USEPA Region 3, is in the middle of a process to upgrade its biomonitoring and biological assessment methods to those currently recommended in the mid-Atlantic region. As part of this effort, a study has been performed to assist the agency to move from a paired-network/reference site approach to a regional reference condition approach, and has led to the development of a proposed stream condition index (SCI) for Virginia’s non-coastal areas (Tetra Tech, 2002). This multimetric index is based on 8 biomonitoring metrics, with a scoring range of 0-100, that are different than those used in the RBP II. A maximum score of 100 represents the best benthic community sites. Current proposed threshold criteria would define “nonimpaired” sites as those with an SCI > 61.9 (the 10th percentile of all scores from 62 reference sites in Virginia), and “impaired” sites as those with an SCI < 56.3 (the 5th percentile). The SCI scores for Mill Creek (Figure 3.3) have clearly gone back and forth between “impaired” and “nonimpaired”, although an overall average score of 60.3 indicates that Mill Creek has a relatively minor impairment.

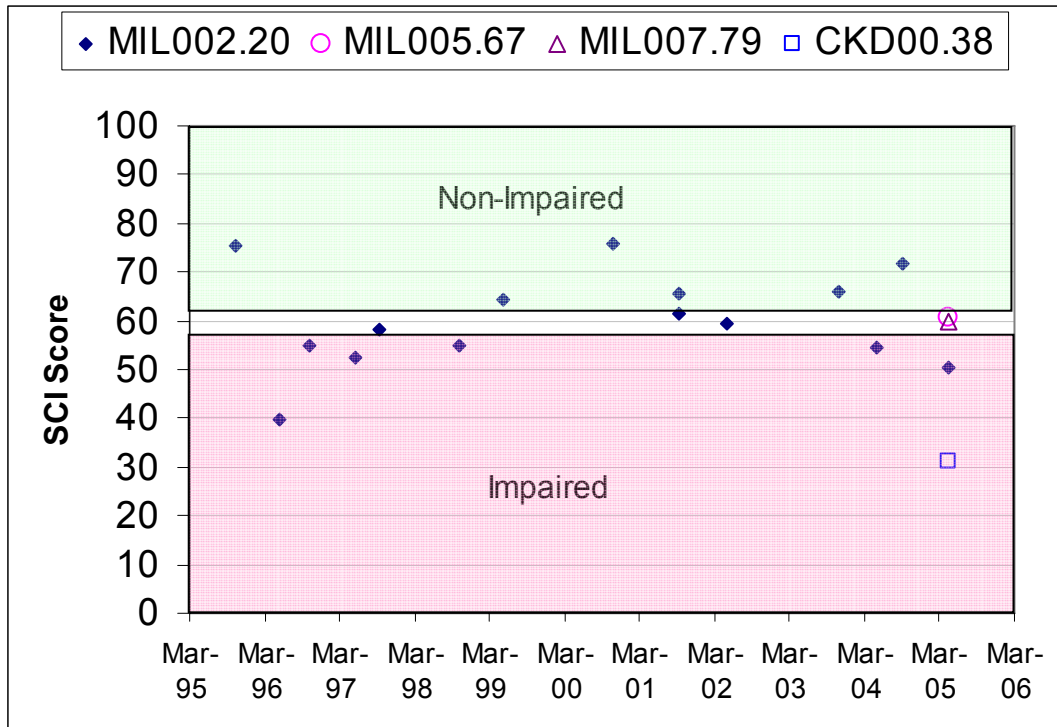


Figure 3.3. Stream Condition Index (Scored against a fixed scale)

CHAPTER 4: BENTHIC STRESSOR ANALYSIS

4.1. Introduction

TMDLs must be developed for a specific pollutant. Since a benthic impairment is based on a biological inventory, rather than on a physical or chemical water quality parameter, the pollutant is not implicitly identified in the assessment, as it is with physical and chemical parameters. The process outlined in EPA's Stressor Identification Guidance Document (USEPA, 2000) was used to identify the critical stressor for Mill Creek. A list of candidate causes was developed from the listing information, biological data, published literature, and stakeholder input. Chemical and physical monitoring data from DEQ monitoring provided additional evidence to support or eliminate the potential candidate causes. Biological metrics and habitat evaluations in aggregate provided the basis for the initial impairment listing, but individual metrics were also used to look for links with specific stressors, where possible. Volunteer monitoring data, land use distribution, Virginia Base Mapping Project (VBMP) aerial imagery, and visual assessment of conditions in and along the stream corridor provided additional information to investigate specific potential stressors. Logical pathways were explored between observed effects in the benthic community, potential stressors, and intermediate steps or interactions that would be consistent in establishing a cause and effect relationship with each candidate cause. The candidate benthic stressors considered in the following sections are ammonia, pH, temperature, toxics, nutrients, organic matter, and sediment. The information in this section is adapted from the original Stressor Analysis Report for Mill Creek (Yagow et al., 2005).

The results of the stressor analysis were divided into the following three categories:

- Non-Stressors: Stressors with data indicating normal conditions, without violations of a governing standard, or without observable

impacts usually associated with a specific stressor. These stressors were eliminated from the list of possible stressors.

- Possible Stressors: Stressors with data indicating possible links, but with inconclusive data, were considered to be possible stressors.
- Most Probable Stressor(s): Stressor(s) with the most consistent data linking it with the poorer benthic metrics, or the most plausible of the possible stressors. This stressor(s) was selected as the most probable stressor(s) and was used for TMDL development.

4.2. Eliminated Stressors

Ammonia

High values of ammonia are toxic to many fish species and may impact the benthic community as well. Most values (66/70) recorded at MIL002.20 (Figure 4.1) were at or below the minimum detection limit (MDL) of 0.04 mg/L, and the maximum value was only 0.13 mg/L, well below its pH- and temperature-dependent water quality standard for that day. Ammonia was eliminated as a possible cause of the benthic impairment.

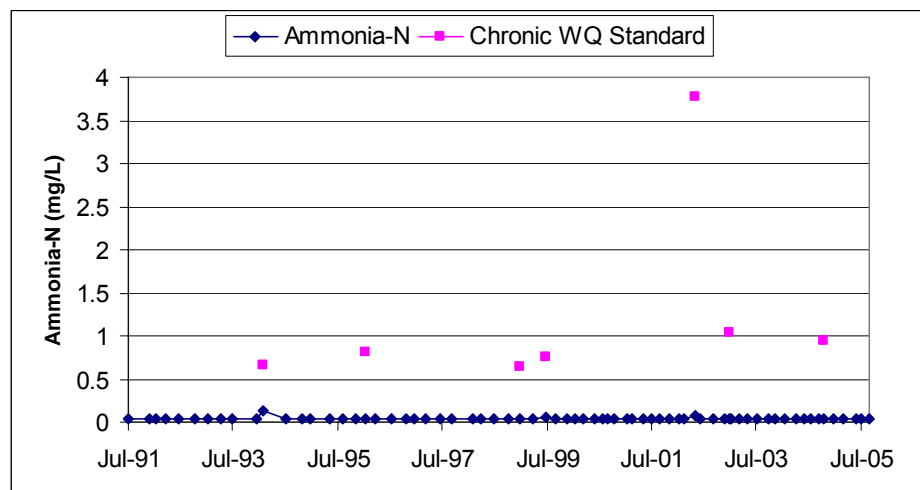


Figure 4.1. Ammonia Concentrations at MIL002.20

pH

Benthic macroinvertebrates require a specific pH range to live and grow. Changes in pH may adversely affect the survival of benthic macroinvertebrates. Treated wastewater and urban runoff can potentially alter in-stream levels of pH.

Only one exceedence of the Class V maximum pH standard (9.5) occurred prior to the 1998 assessed impairment as shown in Figure 4.2. Since then, all measurements have been within the normal range of values. So, pH does not appear to be the cause of the benthic impairment.

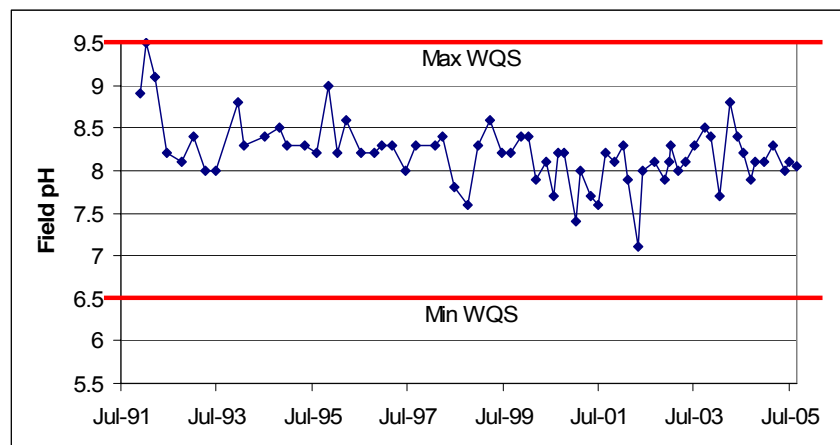


Figure 4.2. Field pH Measurements at MIL002.20

Temperature

Mill Creek is currently classified as a Class V stocked trout stream with a maximum temperature standard of 21°C. Deliberations are underway at DEQ to review the appropriateness of this classification and the temperature criteria for stocked trout waters. The alternative classification is a Class IV wild natural trout stream with a maximum temperature standard of 31°C for Mountainous Zones. The complete absence of riparian cover along many stretches of streams in this watershed may contribute to the elevated higher summer temperatures in Mill Creek. However, this standard was developed to address stocked trout habitat needs, and these slightly elevated summer temperatures do not appear to affect other fish species or benthic macroinvertebrates. If we look at the incidence of summer temperatures above 21°C, about 20.3% of Mill Creek samples (shown in Figure 4.3) exceed this lower threshold, which is less than the 33.3% exceedence

rate of its current non-impaired biological reference stream - Cowpasture River (CWP050.66). Therefore, temperature does not appear to be the cause of the benthic impairment.

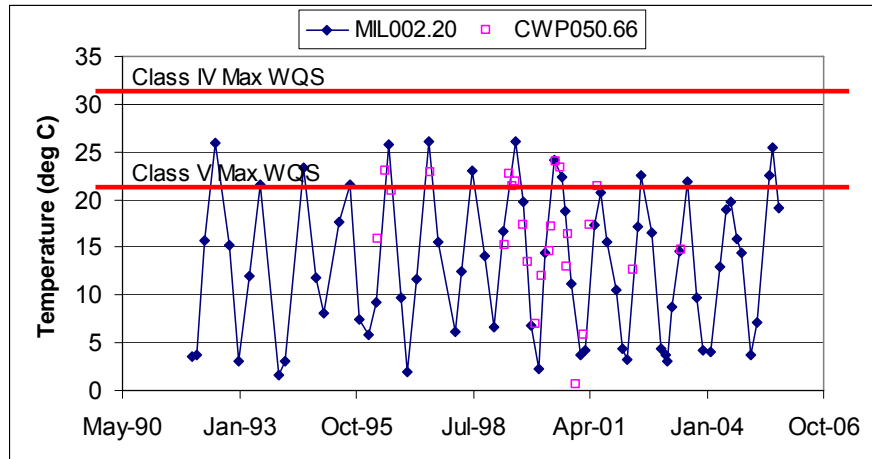


Figure 4.3. Stream Temperature at MIL002.20

Toxics

All benthic samples in the Mill Creek watershed have shown abundant, diverse populations which are inconsistent with sources of toxicity. Three channel bottom sediment samples (Table 4.1) have been tested for toxicity, with no exceedences of any available sediment consensus values. There were a low number of shredders in all benthic populations that could have been caused by toxicity (Table 3.2). However, these low numbers are more likely due to the low level of allochthonous inputs associated with the very poor levels of riparian vegetation along many stretches of stream, rather than to toxicity.

Table 4.1. DEQ Channel Sediment Toxics Monitoring at MIL02.20

| Parameter Code | Sediment Parameter | Dry Weight Units | Sample Collection Date | | | | | | Consensus-Based PECs |
|----------------|--------------------|------------------|------------------------|---|-----------|---|-----------|---|----------------------|
| | | | 7/15/1992 | | 7/29/1996 | | 8/17/2000 | | |
| 1003 | Arsenic | mg/kg | 9 | | 5 | | 7.7 | | 33 |
| 1013 | Beryllium | mg/kg | 5 | U | 5 | U | 5 | U | |
| 1028 | Cadmium | mg/kg | 5 | U | 5 | U | 5 | U | 4.98 |
| 1029 | Chromium | mg/kg | 28 | | 14 | | 27.6 | | 111 |
| 1043 | Copper | mg/kg | 22 | | 14 | | 11.1 | | 149 |
| 1052 | Lead | mg/kg | 19 | | 15 | | 19.8 | | 128 |
| 1053 | Manganese | mg/kg | NULL | | 522 | | 1670 | | |
| 1068 | Nickel | mg/kg | 14 | | 13 | | 17.7 | | 48.6 |
| 1078 | Silver | mg/kg | 5 | U | 5 | U | 5 | U | |
| 1093 | Zinc | mg/kg | 48 | | 34 | | 48.2 | | 459 |
| 1098 | Antimony | mg/kg | NULL | | 8 | | 5 | U | |
| 1108 | Aluminum | mg/kg | NULL | | 6320 | | 16500 | | |
| 1148 | Selenium | mg/kg | 1 | U | 1 | U | 1 | U | |
| 1170 | Iron | mg/kg | NULL | | 15900 | | 24700 | | |
| 34480 | Thallium | mg/kg | 5 | U | 5 | U | 5 | U | |
| 39061 | PCP | µg/kg | 50 | U | 120 | U | 60 | U | |
| 39333 | Aldrin | µg/kg | 100 | U | 50 | U | 20 | U | |
| 39351 | Chlordane | µg/kg | 500 | U | 60 | U | 50 | U | 17.6 |
| 39363 | DDD | µg/kg | 100 | U | 20 | U | 30 | U | 28 |
| 39368 | DDE | µg/kg | 100 | U | 20 | U | 30 | U | 31.3 |
| 39373 | DDT | µg/kg | 100 | U | 50 | U | 30 | U | 62.9 |
| 39383 | Dieldrin | µg/kg | 100 | U | 20 | U | 20 | U | |
| 39393 | Endrin | µg/kg | 100 | U | 50 | U | 40 | U | |
| 39403 | Toxaphene | µg/kg | 1000 | U | 250 | U | 100 | U | |
| 39413 | Heptachlor | µg/kg | 100 | U | 20 | U | 20 | U | |
| 39526 | PCBS | µg/kg | 500 | U | 50 | U | 20 | U | |
| 71921 | Mercury | mg/kg | 0.3 | U | 0.3 | U | 0.3 | U | 1.06 |
| 75045 | Heptachlor epoxide | µg/kg | 100 | U | 20 | U | 20 | U | |
| 79799 | Dicofol (Kelthane) | µg/kg | 100 | U | 120 | U | 60 | U | |

U = analyzed, but not detected. Value is lower limit of detection.

PEC = probable effect concentration.

- Lower detection limit greater than PEC.

4.3. Possible Stressors

Nutrients

Excessive nutrient inputs can lead to excessive algal growth, eutrophication, and low dissolved oxygen concentrations which may adversely affect the survival of benthic macroinvertebrates. In particular, dissolved oxygen levels may become low during overnight hours due to plant respiration.

Nutrients are available in sufficient quantities to support eutrophic conditions. The nitrate levels are slightly elevated (Figure 4.4), while the dissolved phosphorus levels are fairly typical (Figure 4.5) and comparable to the reference watershed. Phosphorus is the limiting nutrient.

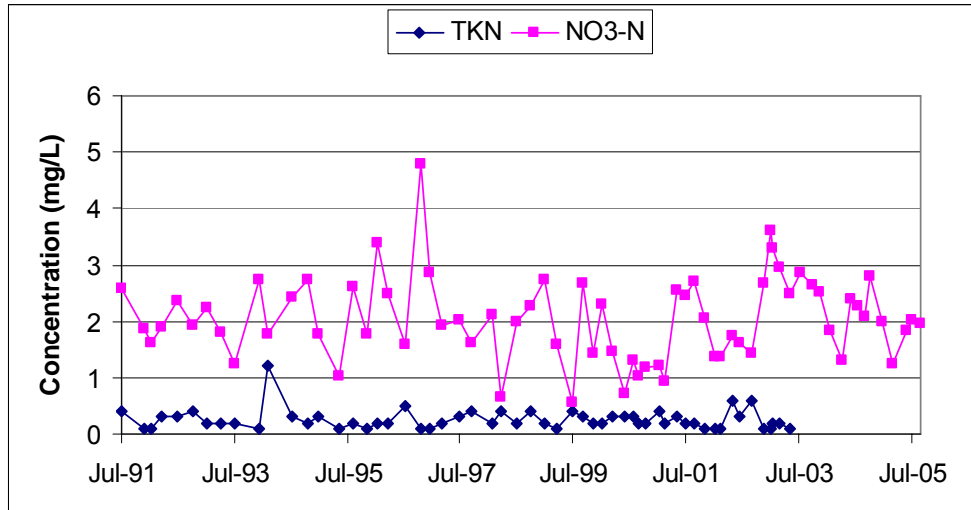


Figure 4.4. TKN and Nitrate-N at MIL002.20

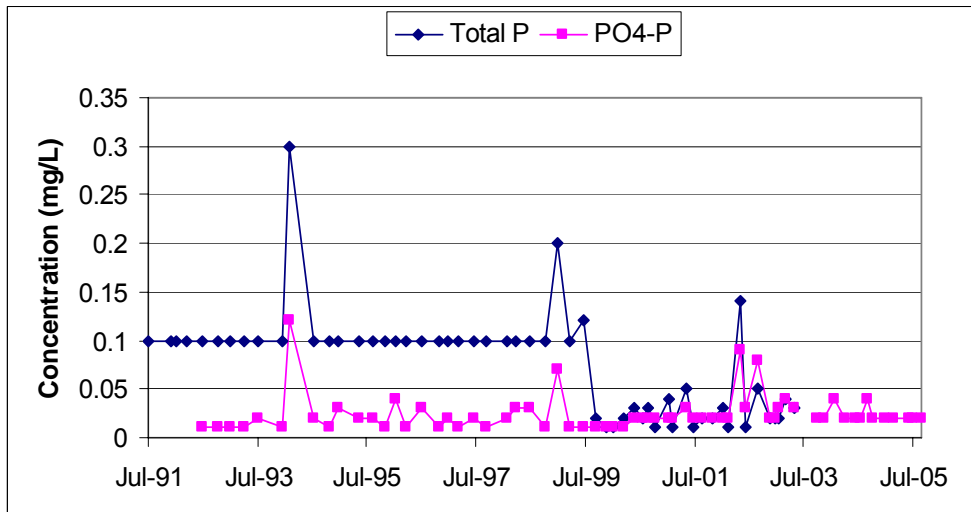


Figure 4.5. Total and Ortho-Phosphorus at MIL002.20

Chironomidae and *hydropsychidae* are two macroinvertebrate species associated with excessive nutrients. At least one of these two species was one of two dominant organisms in many samples (Table 3.1). The dominance of both of these organisms, however, has diminished since the spring of 2002. Prior to that time, *chironomidae* was one of two dominant organisms in 9/11 samples, but only in 2/4 samples since then. Prior to the spring of 2002, *hydropsychidae* was one of two dominant organisms in 6/11 samples, but only in 1/4 samples since then.

Monthly monitoring of dissolved oxygen (DO) showed no exceedences of the state standard (Figure 4.6). In the diurnal DO study, DO levels stayed well

above the minimum DO level of 5.0 mg/L (Figure 4.7). The large change in diurnal concentrations (maximum values are approximately 50% higher than night time DO levels), however, can be indicative of excessive nutrients. There are also large amounts of nutrient-rich poultry litter generated within the watershed, and large numbers of livestock with stream access that could be sources of nutrient input to Mill Creek. The reduced riparian vegetative cover may also promote increased nutrient transport from surface runoff. Therefore, nutrients were considered to be a possible stressor.

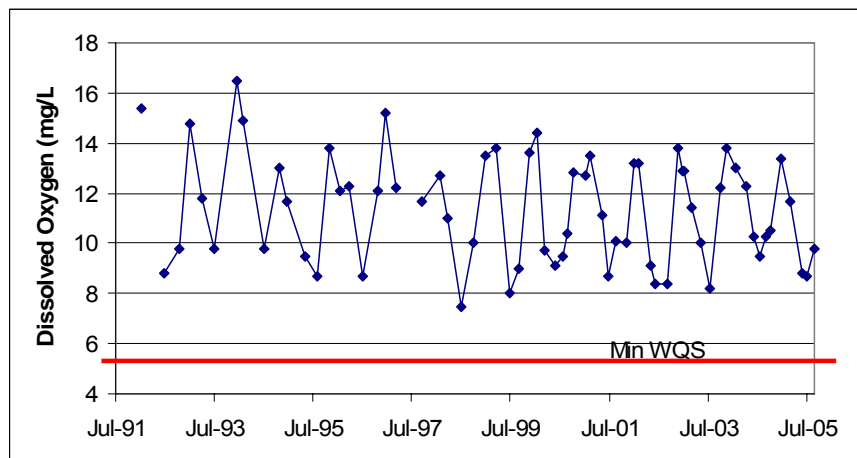


Figure 4.6. Dissolved Oxygen at MIL002.20

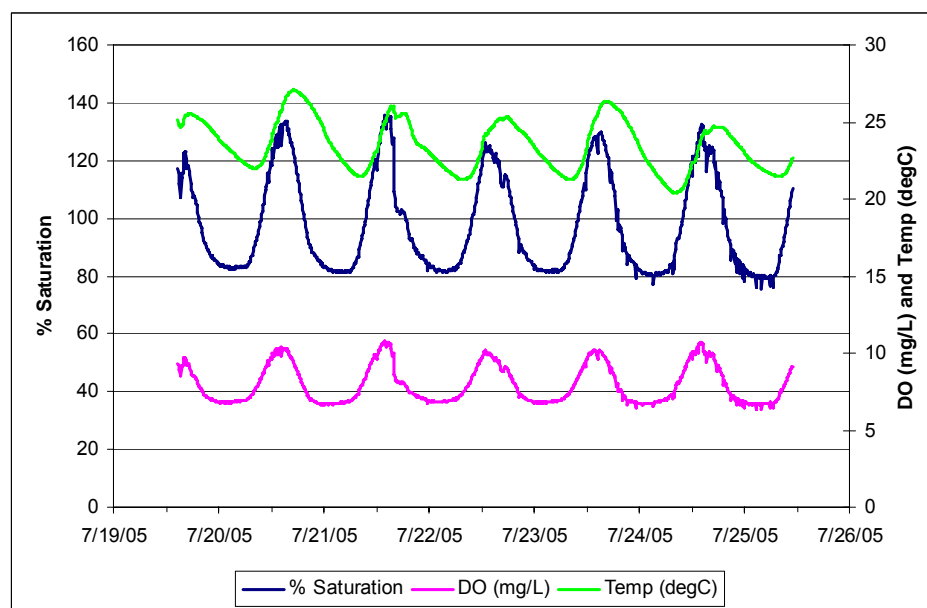


Figure 4.7. Diurnal DO Study at MIL002.20, July 19-25, 2005

Organic Matter

Excessive organic matter can lead to low in-stream dissolved oxygen concentrations which may adversely affect the survival and growth of benthic macroinvertebrates. Potential sources of organic matter include wastewater discharges, agricultural runoff, and livestock manure.

Once again, the dominance of the *hydropsychidae* species, though declining, may be indicative of available organic materials in the stream. The modified family biotic index (MFBI) metric has had a number of high scores (Table 3.2) - indicative of organic pollution, although these scores have exhibited a slightly decreasing trend over time. Finally, low values of the SC/CF metric - the ratio of scrapers (SC) to collector-filterers (CF) - also indicate the relative dominance of organisms that rely on suspended fine particulate organic matter (FPOM) as their primary food source. The low SC/CF numbers occurred prior to 1999 and have shown a sporadically increasing trend since then, although this “improvement” may have been the result of a change in the biological reference site used to calculate the RBP II metrics. These three trends are consistent in indicating a gradually decreasing influence of excess organic matter in the stream. As with nutrients, the large amounts of poultry litter generated within the watershed and the large numbers of livestock with stream access could also be sources of organic matter inputs to Mill Creek. BOD₅ and DO were only monitored through May 2001 and July 1999, respectively (Figure 4.8). BOD₅ concentrations were all fairly low, with many values at or below minimum analysis detection limits; COD concentrations may have been slightly elevated, but not at levels that would indicate high organic matter inputs. Low TKN values relative to nitrates and low % volatile solids both do not support organics as a probable cause (Figure 4.4). Therefore, while organic sources are widely available in the watershed, their influence appears to be gradually decreasing. However, livestock manure seems to be a definite contributor to benthic stress, and since the sources of nutrients and organic matter from livestock manure cannot easily be separated, organic matter was considered as a possible stressor in Mill Creek.

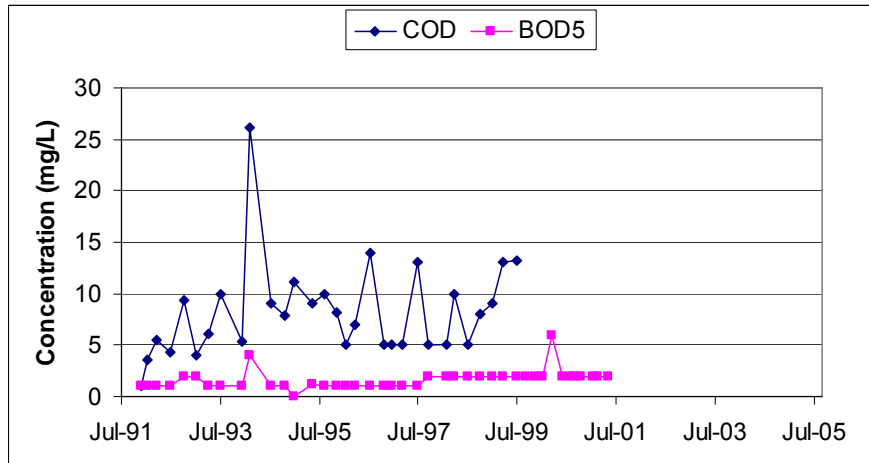


Figure 4.8. COD and BOD₅ at MIL002.20

Sediment

Excessive sedimentation can impair benthic communities through loss of habitat. Excess sediment can fill the pores in gravel and cobble substrate, eliminating macroinvertebrate habitat. Potential sources of sediment include agricultural runoff, residential runoff, forestry operations, construction sites, streambank erosion, and in-stream disturbances.

Eroding stream banks coupled with poor riparian vegetative cover appear to be the dominant contributor of sediment in Mill Creek. Many livestock operations along Crooked Run and stretches of Mill Creek and unnamed tributaries have pasture areas with stream access showing eroded streambanks. In two of the worst benthic samples according to the MAIS metrics (Table 3.3), the %Haptobenthos metric received very poor scores, generally indicating a lack of clean, coarse substrate due to sedimentation. Habitat evaluations of embeddedness and in-stream sediment deposition, and the RBP and SCI ratings, were all poor for the one sample in Crooked Run. Since Crooked Run flows into Mill Creek only about 0.7 miles upstream from the main Mill Creek benthic station (MIL002.20), it could have a major impact on the benthic habitat in that portion of the stream. Aerial imagery (Figure 4.9, Figure 4.10, and Figure 4.11) and a windshield survey of the watershed (Figure 4.12) confirm the severity of the streambank erosion in select areas of the watershed. Upstream segments of Mill Creek have considerably better sediment-related habitat metrics than the portion

of Mill Creek below station MIL005.67. Therefore, sediment also appears to be a probable cause of the benthic impairment.



Figure 4.9. Bare riparian zones with livestock along Crooked Run

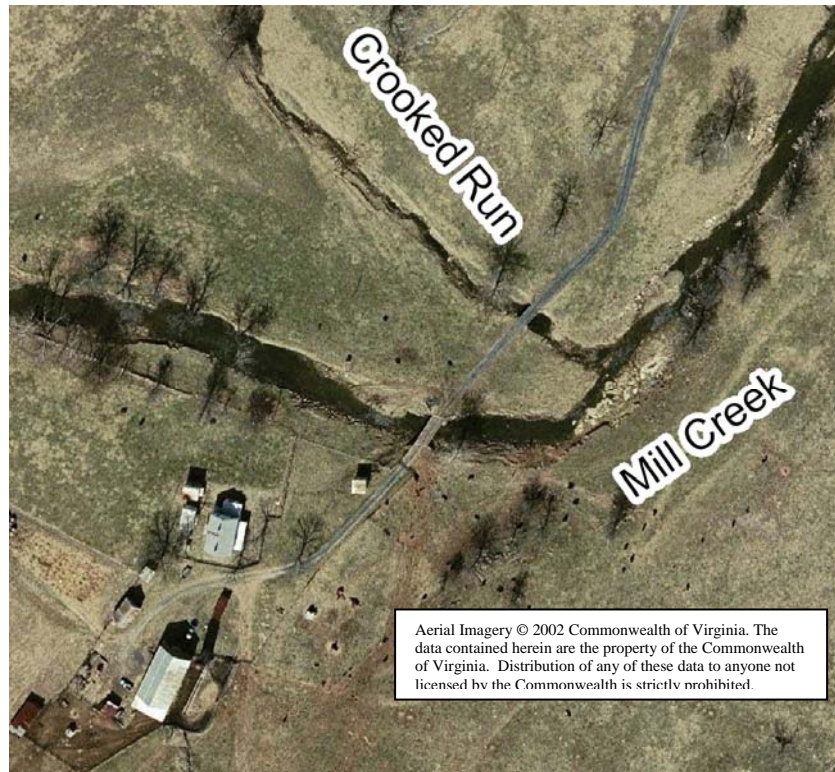


Figure 4.10. Bare riparian areas and livestock impacts - confluence of Crooked Run and Mill Creek



Figure 4.11. Bare riparian corridor along Unnamed Tributary to Mill Creek



Figure 4.12. Eroded streambanks and minimal riparian vegetation along Crooked Run

4.4. Most Probable Stressor

The possible stressors to Mill Creek are nutrients, organic matter, and sediment, with no clearly dominant stressor. The weight-of-evidence approach identified the following evidence in support of sediment as the primary stressor. Low %Haptobenthos metric scores corresponded with two of the poorest samples. Poor riparian vegetative cover, livestock access to streams, and channel streambank degradation were observed along various stream segments, all consistent with an impairment by sediment. The most recent benthic sample at station MIL002.20 was accompanied by two samples upstream on Mill Creek (MIL005.67 and MIL007.79) and one sample on Crooked Run (CKD000.38). Crooked Run enters Mill Creek 0.7 miles above station MIL002.20. The biological condition, RBP, MAIS, and SCI scores were all considerably poorer at the Crooked Run site compared with the Mill Creek sites, as were the sediment-

related metrics - embeddedness, riparian vegetation, and sediment deposition. Because of its proximity to MIL002.20 (the primary monitoring site), this tributary appears to be exerting a major negative influence on the biological communities at MIL002.20.

The following rationale, developed through discussions with the regional DEQ TMDL coordinator and biologist, and state DEQ and DCR personnel, further supports the choice of sediment as the most probable stressor in Mill Creek:

- Many best management practices (BMPs) employed to control sediment result in decreases in the other possible stressors (i.e., nutrients and organics) as well. Best management practices that might be used during implementation include those that would address the open canopy, streambank stability, riparian buffer zones, and livestock access to the stream. Some examples of the synergistic reductions from sediment BMPs are:
 - Reducing livestock access to streams also reduces inputs of organic matter and nutrients from manure
 - Stream buffers reduce overland flow velocities, thus decreasing sediment transport capacity and transport of sediment-attached nutrients, as well as suspended sediment and organic matter.
- The ultimate criteria for judging the success of the TMDL will be the restoration of the benthic community itself. As implementation proceeds, progress will be monitored, and the effectiveness of the implementation strategy will be evaluated.

In summary, the Mill Creek TMDL will be developed and implemented for sediment to address its benthic impairment. Lack of riparian vegetative cover and livestock access to streams appear to be the major sources of stress on the benthic community in Mill Creek. Ambient and biological monitoring data indicate that the impact from the Mill Creek watershed above station MIL005.67 is minor. The problem appears to be localized to segments of Mill Creek and tributaries downstream from station MIL005.67.

CHAPTER 5: THE REFERENCE WATERSHED MODELING APPROACH

5.1. Introduction

Virginia has no numeric in-stream criteria for sediment, so a “reference watershed” approach was used to set allowable sediment loading rates in the impaired watershed.

The reference watershed approach pairs two watersheds - one whose streams are supportive of their designated uses and one whose streams are impaired. This reference watershed may be, but does not have to be, the watershed corresponding to the reference monitoring site used for determining comparative biological metric scores. The reference watershed is selected on the basis of similarity of land use, topographical, ecological, and soils characteristics with those of the impaired watershed. This approach is based on the assumption that reduction of the stressor loads in the impaired watershed to the level of the loads in the reference watershed will result in elimination of the benthic impairment.

The reference watershed approach involves assessment of the impaired reach and its watershed, identification of potential causes of impairment through a benthic stressor analysis, selection of an appropriate reference watershed, model parameterization of the reference and TMDL watersheds, definition of the TMDL endpoint using modeled output from the reference watershed, and development of alternative TMDL reduction (allocation) scenarios.

5.2. Selection of Reference Watershed for Sediment

5.2.1. Comparison of Potential Watersheds

The list of potential reference watersheds included watersheds corresponding with each of the biological monitoring reference sites used with Mill Creek, other watersheds used as references for previous TMDLs in the New River and Shenandoah Valley area, and two upstream drainages within Mill Creek. Minimal differences exist among the eco-region classifications for all of

the potential reference watersheds. Table 5.1 compares the various physical and sediment-related characteristics of the candidate reference watersheds to the characteristics of the impaired watershed. The characteristics chosen to be representative of sediment generation and transport were land use distribution, non-forested average soil erodibility, and average non-forested percent slope. The Universal Soil Loss Equation (USLE) K-factor was used as an index of the erosivity of soils in the watersheds, and was calculated as a weighted average of all soil K-factors in each watershed.

Table 5.1. Reference Watershed Comparisons for MIL002.20

| Station ID | Stream Name | Area (ha) | Landuse Distribution | | | Non-Forested | | Elevation (meters) | 2000 Population | | Latest SCI | | SubEco Region |
|-------------------------------------|-------------------|-----------|----------------------|------------|---------|-----------------|-----------|--------------------|-----------------|----------|------------|--------|---------------|
| | | | Urban (%) | Forest (%) | Agr (%) | SSURGO K-factor | Slope (%) | | Non-Sewered | (pop/ha) | Score | Date | |
| Impaired Watershed | | | | | | | | | | | | | |
| MIL002.20 | Mill Creek | 10,390 | 1% | 60% | 40% | 0.299 | 8.66 | 402.4 | 1,609 | 0.15 | 50.40 | May-05 | 67a |
| Potential TMDL Reference Watersheds | | | | | | | | | | | | | |
| OPE034.53 | Opequon Creek* | 15,123 | 14% | 28% | 58% | 0.310 | 5.60 | 224.1 | 16,322 | 1.08 | 64.03 | Oct-04 | 67a |
| STC004.27 | Strait Creek | 672 | 0% | 71% | 29% | NA | 18.50 | 988.3 | 57 | 0.08 | 61.70 | May-05 | 67a |
| STY004.24 | Stony Creek | 19,768 | 1% | 87% | 12% | 0.260 | 11.67 | 507.7 | 2,126 | 0.11 | 43.63 | May-05 | 67a |
| BLP000.79 | Bullpasture River | 28,495 | 0% | 81% | 18% | NA | 7.73 | 794.6 | 527 | 0.02 | 74.92 | Nov-02 | 67a |
| CWP050.66 | Cowpasture River | 56,604 | 0% | 86% | 14% | NA | 13.81 | 748.4 | 994 | 0.02 | 65.82 | May-05 | 67a |
| HYS001.41 | Hays Creek | 20,801 | 0% | 52% | 48% | 0.310 | 12.53 | 526.2 | 1,600 | 0.08 | 65.66 | Oct-03 | 67a |
| JKS067.00 | Jackson River | 31,429 | 0% | 81% | 19% | NA | 13.93 | 848.7 | 705 | 0.02 | 73.87 | Oct-00 | 67a |
| TOM002.19 | Toms Creek | 9,070 | 2% | 70% | 28% | 0.310 | 12.92 | 662.7 | 4,775 | 0.53 | 68.60 | Oct-01 | 67f/h |
| SNK012.06 | Sinking Creek | 12,860 | 0% | 62% | 38% | NA | 18.24 | 771.6 | 928 | 0.07 | 64.40 | Apr-02 | 67f |
| TOM012.78 | Toms Creek | 2,067 | 2% | 72% | 26% | 0.300 | 11.59 | 688.8 | 833 | 0.40 | 68.71 | Sep-03 | 67f |
| MIL005.67 | Mill Creek | 6,156 | 1% | 81% | 18% | 0.275 | 10.76 | 435.2 | 782 | 0.13 | 60.70 | May-05 | 67a |
| MIL007.79 | Mill Creek | 4,779 | 1% | 90% | 9% | 0.253 | 11.55 | 453.0 | 555 | 0.12 | 59.70 | May-05 | 67a |

* Land use was digitized and interpreted from DOQQ imagery.

NA = SSURGO soils data not available for these watersheds

- Impaired watershed
 - Closest matches

5.2.2. The Selected Reference Watershed

Based on the information presented in the previous sections, the upstream portion of the Mill Creek watershed, above station MIL005.67, was selected as the reference watershed for Mill Creek. The proximity of the watershed and the fact that the upstream portion was not impaired was the basis for selection of this watershed. The similarities of land use (though of slightly different proportions) should provide target loads appropriate for the downstream impaired segment.

5.3. Sediment TMDL Modeling Endpoint

The reference watershed approach for Mill Creek uses the sediment loading rate in the area-adjusted, non-impaired, upper Mill Creek (MIL005.67) watershed as the TMDL target endpoint. Alternative TMDL scenarios were created that would meet the TMDL target within the impaired Mill Creek

watershed (MIL002.20). Each scenario used variable percentage reductions of the existing loads from the different source categories. Reductions in sediment load to levels found in the reference watershed are expected to allow benthic conditions to return to a non-impaired state.

CHAPTER 6: MODELING PROCESS FOR TMDL DEVELOPMENT

6.1. Source Assessment of Sediment

Sediment is generated in the Mill Creek watershed through the processes of surface runoff, streambank and channel erosion, as well as from background geologic forces. Sediment generation is accelerated through human-induced land-disturbing activities related to a variety of agricultural, forestry, and urban land uses. In Mill Creek, these activities relate primarily to livestock access to streams and lack of riparian vegetation.

6.1.1. Surface Runoff

During runoff events, sediment loading occurs from both pervious and impervious surfaces around the watershed. For pervious areas, soil is detached by rainfall impact or shear stresses created by overland flow and transported by overland flow to nearby streams. This process is influenced by vegetative cover, soil erodibility, slope, slope length, rainfall intensity and duration, and land management practices. During periods without rainfall, dirt, dust and fine sediment build up on impervious areas through dry deposition, which is then subject to washoff during rainfall events. Sediment generated from impervious areas can be reduced through the use of management practices that reduce the surface load subject to washoff.

6.1.2. Channel and Streambank Erosion

Pasture areas accessible to streams are often associated with sediment loading through the activity of livestock on their streambanks. Livestock hooves on streambanks detach clumps of soil, and push the loosened soil downslope and into streams adjacent to these areas, delivering sediment to the stream independent of runoff events. Impervious areas tend to increase the percentage of rainfall that runs off the land surface leading to larger volumes of runoff with higher peak flows and greater channel erosion potential.

6.1.3. Point Source TSS Loads

Fine sediment is included in total suspended solids (TSS) loads that are contributed from the one permitted industrial stormwater runoff facility and the eight single-family homes included under the 1,000-gpd general permit within the watershed.

6.2. *GWLF Model Description*

The Generalized Watershed Loading Functions (GWLF) model was developed for use in ungaged watersheds (Haith et al., 1992), and was chosen for the modeling required for the Mill Creek TMDL. The loading functions upon which the model is based are compromises between the empiricism of export coefficients and the complexity of chemical simulation models. GWLF is a continuous simulation spatially-lumped parameter model that operates on a daily time step. The model estimates runoff, sediment, and dissolved and attached nitrogen and phosphorus loads delivered to streams from complex watersheds with a combination of point and non-point sources of pollution. The model considers flow inputs from both surface runoff and groundwater. The hydrology in the model is simulated with a daily water balance procedure that takes into consideration types of storages within the system. Runoff is generated based on the Soil Conservation Service's Curve Number method as presented in Technical Release 55 (SCS, 1986). Erosion is generated using a modification of the Universal Soil Loss Equation. Sediment supply uses a delivery ratio together with the erosion estimates, and sediment transport takes into consideration the transport capacity of the runoff. Stream bank and channel erosion was calculated using an algorithm by Evans et al. (2003) as incorporated in the AVGWLF version (Evans et al., 2001) of the GWLF model and corrected for a flow accumulation coding error.

The GWLF model operates on three input files for weather, transport, and nutrient data. The weather file contains daily temperature and precipitation for the period of simulation. The transport file contains input data primarily related to hydrology and sediment transport, while the nutrient file contains primarily

nutrient values for the various land uses, point sources, and septic system types. The Visual Basic™ version of GWLF with modifications for use with ArcView was used in this study (Evans et al., 2001). The following additional modifications related to sediment were made to the Penn State Visual Basic version of the GWLF model, as incorporated in their ArcView interface for the model, AvGWLF v. 3.2:

- Urban sediment buildup was added as a variable input.
- Urban sediment washoff from impervious areas was added to total sediment load.
- Formulas for calculating monthly sediment yield by land use were corrected.
- Mean channel depth was added as a variable to the streambank erosion calculation.

The VT modified version of GWLF (gwlf2005b.exe) that includes the December 2005 correction to the flow accumulation calculation in the channel erosion routine was used.

6.3. Supplemental Post-Model Processing

After modeling was performed on individual and cumulative sub-watersheds, the model output was post-processed in a Microsoft Excel™ spreadsheet to summarize the modeling results and to account for existing levels of agricultural best management practices (BMPs) already implemented within the Mill Creek watershed.

The effect of existing agricultural BMPs was based on the Virginia Department of Conservation and Recreation's (DCR) State Cost-Share Database. The DCR database tracks the implementation of BMPs within each state HUP watershed. These data are then used by EPA's Chesapeake Bay Program to calculate sediment reduction and pass-through fractions of the sediment load from each land use in each HUP for use with the Chesapeake Bay model and with the Virginia 2002 Statewide NPS Pollution Assessment (Yagow et al., 2002). Since Mill Creek lies within the B48 watershed, the modeled land use categories used for this TMDL study were assigned sediment pass-through fractions for related land use categories from the B48 watershed. Modeled

sediment loads within each land use category were then multiplied by their respective pass-through fractions to simulate the reduced loads resulting from existing BMPs.

6.4. Input Data Requirements

6.4.1. Climate Data

For modeling purposes, the climate in Mill Creek watershed was characterized by meteorological observations from the National Weather Service Cooperative Station 442663 at Edinburg, Virginia. The Edinburg station is located north of the watershed and 7.7 miles (12.5 km) from the DEQ monitoring station MIL002.20. The period of record used for modeling was an eight-year period from April 1997 through March 2005, with the preceding year of data used to initialize storage parameters. The locations of Mill Creek and the Edinburg station are shown in Figure 6.1.

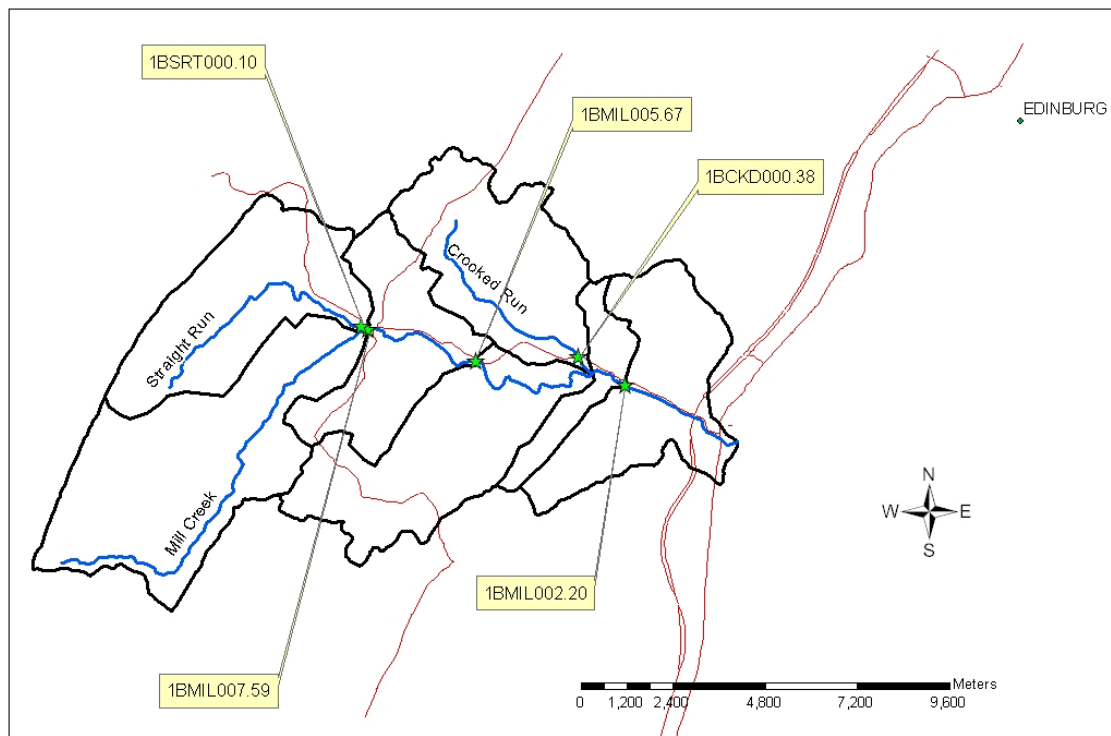


Figure 6.1. Location of Mill Creek and Weather Station

6.4.2. Land Use

Using the 1992 National Land Characterization Dataset (NLCD), 12 land use types were defined for the Mill Creek watershed. The NLCD land use classification categories were consolidated into a smaller number of categories based on the similarities in associated sediment sources, as shown in Table 6.1. The water category was not simulated. The cropland category was subdivided into “High-Till” and “Low-Till” and the pasture/hay category was subdivided into “Pasture” and “Hay” categories based on percentages assessed during the 2002 Statewide NPS Pollution Assessment study (Yagow et al., 2002). The resulting 9 land use categories and their distribution within the Mill Creek watersheds are shown in Table 6.2. During modeling with GWLF, the pervious and impervious portions of the residential and commercial categories were modeled separately, leading to 12 simulated categories of land use. Land use within Mill Creek was assumed to remain fairly stable in the near future, so TMDL allocation scenarios were modeled based on existing land use conditions.

Table 6.1. Consolidation of NLCD Land Use Categories for Mill Creek

| TMDL Land Use Categories | Pervious/Impervious (percentage) | NLCD Land Use Categories |
|----------------------------------|---|---|
| Cropland | Pervious (100%) | Row crops (82) |
| Pasture/Hay | Pervious (100%) | Pasture/hay (81) |
| Forest | Pervious (100%) | Deciduous forest (41), Evergreen forest (42), Mixed forest (43), Woody wetland (91), Emergent herbaceous (92) |
| Transitional | Pervious (100%) | Transitional (33) |
| Low Density Residential (LDR) | Pervious (88%) Impervious (12%) | Low intensity residential (21) |
| Medium Density Residential (MDR) | Pervious (70%) Impervious (30%) | High intensity residential (22) |
| Commercial | Pervious (21%) Impervious (79%) | Commercial/industrial/transportation (23) |
| Water | | Open water (11) |

Table 6.2. Land Use Distribution in Mill Creek Watersheds

| Land Use Category | Mill Creek (ha) | Mill Creek 5.67 (ha) | Mill Creek 5.67 Area-adjusted (ha) |
|--------------------------|------------------------|-----------------------------|---|
| High-Till cropland | 168.7 | 24.7 | 48.3 |
| Low-Till cropland | 100.9 | 14.7 | 28.9 |
| Pasture | 3,566.9 | 731.9 | 1,432.9 |
| Hay | 1,684.7 | 345.7 | 676.8 |
| Forest | 6,346.6 | 4,996.3 | 9,781.5 |
| Transitional | 15.7 | 14.3 | 27.9 |
| LDR - pervious | 111.3 | 20.0 | 39.2 |
| MDR - pervious | 1.7 | 0.0 | 0.0 |
| Commercial - pervious | 6.0 | 0.0 | 0.0 |
| LDR - pervious | 15.2 | 2.7 | 5.3 |
| MDR - pervious | 0.7 | 0.0 | 0.0 |
| Commercial - pervious | 22.6 | 0.1 | 0.1 |
| Total Land Area | 12,041.0 | 6,150.4 | 12,041.0 |
| % Agriculture | 45.9% | 18.2% | 18.2% |
| % Urban | 1.4% | 0.6% | 0.6% |
| % Forest | 52.7% | 81.2% | 81.2% |

6.4.3. GWLF Parameter Evaluation

All parameters were evaluated in a consistent manner between the two watersheds, in order to ensure their comparability for the reference watershed approach. All GWLF parameter values were evaluated from a combination of GWLF user manual guidance (Haith et al., 1992), AVGWLF procedures (Evans et al., 2001), procedures developed during the 2002 statewide NPS pollution assessment (Yagow et al., 2002), and best professional judgment. Parameters were generally evaluated using GWLF manual guidance, except where noted otherwise. Hydrologic and sediment parameters are all included in GWLF's transport input file, with the exception of urban sediment buildup rates, which are in the nutrient input file. Descriptions of each of the hydrologic and sediment parameters are listed below according to whether the parameters were related to the overall watershed, to the month of the year, or to individual land uses.

6.4.4. Hydrology Parameters

Watershed-Related Parameter Descriptions

- Unsaturated Soil Moisture Capacity (SMC): The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute - available water capacity.
- Recession coefficient (day⁻¹): The recession coefficient is a measure of the rate at which streamflow recedes following the cessation of a storm, and is approximated by averaging the ratios of streamflow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph. This parameter was evaluated using the following relationship from Lee et al. (2000): $\text{RecCoeff} = 0.045 + 1.13 / (0.306 + \text{Area in square kilometers})$
- Seepage coefficient (day⁻¹): The seepage coefficient represents the amount of flow lost as seepage to deep storage and was set to zero for Mill Creek.

The following parameters were initialized by running the model for a 1-year period prior to the period used for load calculation:

- Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone.
- Initial saturated storage (cm): Initial depth of water stored in the saturated zone.
- Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation.
- Antecedent Rainfall for each of 5 previous days (cm): The amount of rainfall on each of the five days preceding the first day in the weather file

Month-Related Parameter Descriptions

- Month: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model and its assumption that all annual detached sediment is flushed from the system at the end of each Apr-Mar cycle.
- ET CV: Composite evapotranspiration cover coefficient, calculated as an area-weighted average from land uses within each watershed.
- Hours per Day: Mean number of daylight hours.
- Erosion Coefficient: This is a regional coefficient used in Richardson's equation for calculating daily rainfall erosivity. Each region is assigned separate coefficients for the months October-March, and for April-September.

Land Use-Related Parameter Descriptions

- Curve Number: The SCS curve number (CN) is used in calculating runoff associated with a daily rainfall event, evaluated using SCS TR-55 guidance.

6.4.5. Sediment Parameters

Watershed-Related Parameter Descriptions

- Sediment delivery ratio: The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream, calculated as an inverse function of watershed size (Evans et al., 2001).

Land Use-Related Parameter Descriptions

- USLE K-factor: The soil erodibility factor was calculated as an area-weighted average of all component soil types.
- USLE LS-factor: This factor is calculated from slope and slope length measurements by land use. Slope is evaluated by GIS analysis, and slope length is calculated as an inverse function of slope.
- USLE C-factor: The vegetative cover factor for each land use was evaluated following GWLF manual guidance, Wischmeier and Smith (1978), and Hession et al. (1997).
- Daily sediment buildup rate on impervious surfaces: The daily amount of dry deposition deposited from the air on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.

Streambank Erosion Parameter Descriptions (Evans et al., 2003)

- % Developed land: percentage of the watershed with urban-related land uses – defined as all land in MDR, HDR, and COM land uses, as well as the impervious portions of LDR.
- Animal density: calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by the watershed area in acres.
- Curve Number: area-weighted average value for the watershed.
- K Factor: area-weighted USLE soil erodibility factor for the watershed.
- Slope: mean percent slope for the watershed.
- Stream length: calculated as the total stream length of natural stream channel, in meters. Excludes any non-erosive hardened and piped sections of the stream.
- Stream length with livestock access: calculated as the total stream length in the watershed where livestock have unrestricted access to streams, resulting in streambank trampling, in meters.
- Mean channel depth (m): calculated from relationships developed either by the Chesapeake Bay Program or by USDA-NRCS by physiographic region, of the general form $y = a * A^b$, where y = mean channel depth in ft, and A = drainage area in square miles (USDA-NRCS, 2005).

6.5. Accounting for Sediment Pollutant Sources

6.5.1. Surface Runoff

Pervious area sediment loads were modeled explicitly in the GWLF model using sediment detachment based on a modified USLE erosion algorithm, and a

sediment delivery ratio to calculate edge-of-watershed loads, reported on a monthly basis by land use. Impervious area sediment loads were modeled explicitly in the GWLF model using an exponential buildup-washoff algorithm.

6.5.2. Channel and Streambank Erosion

Streambank erosion was modeled explicitly within the GWLF model using a modification of the routine included in the AVGWLF version of the GWLF model (Evans et al., 2001). This routine calculates average annual streambank erosion as a function of percentage developed land, average area-weighted curve number (CN) and K-factors, watershed animal density, average slope, streamflow volume, mean channel depth, and total stream length in the watershed.

6.5.3. Point Source

There is one permitted industrial stormwater runoff discharge in Mill Creek and eight single-family homes permitted under the 1,000-gpd general permit in the watershed. Permitted loads for the industrial stormwater facility were calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 60 mg/L. Average annual modeled runoff (67.34 cm) was calculated by multiplying the maximum annual modeled runoff depth for commercial pervious land uses (11.35 cm) and impervious land uses (82.23 cm) by their respective percentages (21% pervious, 79% impervious). The load from each single-family home unit was calculated as the maximum permitted daily flow and maximum TSS concentration allowed under this type of permit (1,000 gpd and 30 mg/L). This translated into an annual TSS load of 0.0415 t/yr for each unit as shown in Table 6.3.

Table 6.3. Permitted TSS Loads in Mill Creek Watershed

| Permit ID | Type | Permitted Daily Flow (MGD) | Permitted Ave. TSS (mg/L) | Drainage Area (acres) | Modeled Runoff (cm/yr) | Permitted Annual TSS Load (t/yr) |
|----------------|-----------------------|----------------------------|---------------------------|-----------------------|------------------------|----------------------------------|
| VAR050963 | Industrial Stormwater | NA | 60 | 3.66 | 67.34 | 0.60 |
| General Permit | General Permit | 0.001 | 30 | NA | NA | 0.33 |

6.6. Accounting for Critical Conditions and Seasonal Variations

6.6.1. Critical Conditions

The GWLF model is a continuous simulation model that uses daily time steps for weather data and water balance calculations. The period of rainfall selected for modeling was chosen as a multi-year period that was representative of typical weather conditions for the area, and included “dry”, “normal” and “wet” years. The model, therefore, incorporated the variable inputs needed to represent critical conditions during low flow - generally associated with point source loads - and critical conditions during high flow - generally associated with nonpoint source loads.

6.6.2. Seasonal Variability

The GWLF model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model also allows for monthly-variable parameter inputs for evapotranspiration cover coefficients, daylight hours/day, and rainfall erosivity coefficients for user-specified growing season months.

6.7. GWLF Model Parameters

The GWLF model was originally developed for use in non-gaged watersheds (Haith et al., 1992), although hydrologic calibration has been recommended where observed flow data is available (Dai et al., 2000). However, since observed daily flow data was not available in the Mill Creek watershed, hydrologic calibration was not performed. Therefore, the GWLF parameters were evaluated using GWLF user manual guidance and professional judgment. Since the reference watershed approach sets target loads based on relative loads generated by the impaired and TMDL reference watersheds, both watersheds were calibrated in a similar manner to ensure comparability of simulated loads, consistent with the assumptions in the reference watershed approach.

The GWLF parameter values evaluated for both watersheds are shown in Table 6.4 through Table 6.6. Table 6.4 lists the various watershed-wide

parameters and their values, Table 6.5 displays the monthly variable evapotranspiration cover coefficients, and Table 6.6 shows the land use-related parameters - runoff curve numbers (CN) and the Universal Soil Loss Equation's KLSCP product - used for erosion modeling.

Table 6.4. GWLF Watershed Parameters for Mill Creek

| GWLF Watershed Parameters | units | Mill Creek | Mill Creek 5.67 Area-adjusted |
|--|----------------------|-------------------|--------------------------------------|
| recession coefficient | (day ⁻¹) | 0.0544 | 0.0544 |
| seepage coefficient | (day ⁻¹) | 0.0000 | 0.0000 |
| sediment delivery ratio | | 0.1084 | 0.1084 |
| unsaturated water capacity | (cm) | 15.34 | 13.62 |
| erosivity coefficient (Nov - Apr) | | 0.1 | 0.1 |
| erosivity coefficient (growing season) | | 0.3 | 0.3 |
| % developed land | (%) | 1.4 | 0.6 |
| no. of livestock | (AU) | 2,383 | 797 |
| area-weighted runoff curve number | | 74.91 | 72.75 |
| area-weighted soil erodibility | | 0.314 | 0.303 |
| area-weighted slope | (%) | 7.96 | 10.76 |
| aFactor | | 0.0000891 | 0.0000649 |
| total stream length** | (m) | 37,839.1 | 44,496.8 |
| Mean Channel Depth | (m) | 0.922 | 0.922 |

Table 6.5. GWLF Monthly Evapotranspiration Cover Coefficients

| Watershed | Apr | May | Jun | Jul* | Aug | Sep | Oct | Nov | Dec | Jan** | Feb | Mar |
|--------------------------------------|------------|------------|------------|--------------|------------|------------|------------|------------|------------|--------------|------------|------------|
| Mill Creek | 0.985 | 0.993 | 0.996 | 0.996 | 0.996 | 0.987 | 0.926 | 0.866 | 0.840 | 0.822 | 0.909 | 0.968 |
| Mill Creek 5.67 Area-adjusted | 0.987 | 0.995 | 0.998 | 0.998 | 0.998 | 0.989 | 0.923 | 0.857 | 0.828 | 0.809 | 0.904 | 0.968 |

* July values represent the maximum composite ET coefficients during the growing season.

** Jan values represent the minimum composite ET coefficients during the dormant season.

Table 6.6. GWLF Land Use Parameters for Mill Creek - Existing Conditions

| Landuse | Mill Creek | | Mill Creek 5.67 Area-adjusted | |
|---|-------------------|-----------|--------------------------------------|-----------|
| | KLSCP | CN | KLSCP | CN |
| High-Till cropland | 0.2778 | 85.7 | 0.5496 | 85.6 |
| Low-Till cropland | 0.1223 | 83.9 | 0.2420 | 83.7 |
| Pasture | 0.0172 | 78.1 | 0.0226 | 77.9 |
| Hay | 0.0172 | 77.2 | 0.0226 | 77.0 |
| Forest | 0.0016 | 71.8 | 0.0017 | 71.5 |
| Transitional | 0.3922 | 90.6 | 0.4028 | 90.4 |
| Low density residential - pervious | 0.0029 | 78.1 | 0.0044 | 77.9 |
| Medium density residential - pervious | 0.0013 | 78.1 | 0.0000 | 77.9 |
| Commercial - pervious | 0.0021 | 78.1 | 0.0016 | 77.9 |
| Low density residential - impervious | 0.0000 | 91.7 | 0.0000 | 91.7 |
| Medium density residential - impervious | 0.0000 | 98.0 | 0.0000 | 98.0 |
| Commercial - impervious | 0.0000 | 98.0 | 0.0000 | 98.0 |

CHAPTER 7: TMDL ALLOCATIONS

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991).

7.1. Sediment TMDL

7.1.1. Background

The sediment TMDL to address a benthic impairment for the Mill Creek (MIL002.20) watershed was developed using a reference watershed approach, with Mill Creek above MIL005.67 selected as the TMDL reference watershed. For TMDL modeling, a common weather input data set was used for the 8-yr period, April 1997 - March 2005.

7.1.2. Existing Conditions

The existing sediment loads were modeled as 8-yr average annual loads for each watershed and are listed in Table 7.1 by source category, annual watershed load, and sediment unit area loads for individual land uses.

Table 7.1. Existing Sediment Loads

| Sediment Sources | Mill Creek | | Area-adjusted Mill Creek 5.67 | |
|------------------------------------|-------------------|---------------|--|---------------|
| | (t/yr) | (t/ha) | (t/yr) | (t/ha) |
| High Till | 2,335.7 | 13.84 | 708.6 | 14.67 |
| Low Till | 557.7 | 5.53 | 171.8 | 5.95 |
| Pasture | 2,523.4 | 0.71 | 719.3 | 0.50 |
| Hay | 858.0 | 0.51 | 251.8 | 0.37 |
| Forest | 403.0 | 0.06 | 241.5 | 0.02 |
| Transitional | 598.5 | 38.07 | 382.1 | 13.69 |
| Pervious Urban | 15.1 | 0.13 | 4.7 | 0.12 |
| Impervious Urban | 15.6 | 0.41 | 1.2 | 0.22 |
| Channel Erosion | 71.8 | | 41.0 | |
| Permitted Point Sources | 0.9 | | 0.4 | |
| Watershed Totals | 7,379.8 | | 2,522.5 | |
| Target Sediment TMDL Load = | | | 2,522.5 | t/yr |

The sediment TMDL for Mill Creek is the sum of the three required components - WLA, LA, and MOS - as quantified in Table 7.2.

Table 7.2 Mill Creek Sediment TMDL (t/yr)

| TMDL (t/yr) | WLA (t/yr) | LA (t/yr) | MOS (t/yr) |
|------------------------|--|----------------------|-----------------------|
| 2,522.5 | 0.9 | 2,269.3 | 252.2 |
| | VAR050943 Hepner Blocks: 0.6 8 - 1000gpd General Permits: 0.3 | | |

The TMDL for the impaired Mill Creek watershed was calculated as the average annual sediment load from the area-adjusted Mill Creek watershed above station MIL005.67 for existing conditions. An explicit margin of safety (MOS) of 10% was used in the TMDL to reflect the relative increase in uncertainty, compared to the MOS of 5% typically used in TMDLs for the more complex modeling of bacteria. The waste load allocation (WLA) was included as the contribution from the industrial stormwater facility and the eight 1,000-gpd units covered under the general permit. The load allocation (LA) - the allowable sediment load from nonpoint sources - was calculated as the TMDL minus the MOS minus the WLA.

Changes in future land use distribution and sediment sources were judged to be minimal, and were modeled as constant. The TMDL was based, therefore, on existing land uses and sediment sources.

7.1.3. Waste Load Allocation

Waste load allocations were assigned to the one industrial stormwater facility and the eight units encompassed under the general permit in the Mill Creek watershed. Point sources were represented in the allocation scenarios the same as they were for existing conditions. As permitted sources, no reductions were required from these point sources in the TMDL.

7.1.4. Allocation Scenarios

For development of the allocation scenarios, overland non-point sediment sources were grouped into the following three categories: Agriculture, Residential/Urban, and Forestry. Additionally, Channel Erosion and Point Sources were listed as separate categories. Three alternative allocation scenarios were developed, as illustrated in Table 7.3.

Table 7.3 Sediment TMDL Load Allocation Scenarios for Mill Creek

| Source Category | Reference Mill Creek (t/yr) | Mill Creek Sediment Load | | | | | | |
|-------------------|-----------------------------|--------------------------|----------------------------------|---------------------------|----------------------------------|---------------------------|----------------------------------|---------------------------|
| | | Existing (t/yr) | TMDL Alternative 1 (% reduction) | TMDL Alternative 1 (t/yr) | TMDL Alternative 2 (% reduction) | TMDL Alternative 2 (t/yr) | TMDL Alternative 3 (% reduction) | TMDL Alternative 3 (t/yr) |
| Agriculture | 1,851.5 | 6,274.9 | 81% | 1,165.3 | 73% | 1,678.7 | 69% | 1,929.8 |
| Residential/Urban | 388.0 | 629.2 | 0% | 629.2 | 73% | 168.3 | 69% | 193.5 |
| Forestry | 241.5 | 403.0 | 0% | 403.0 | 0% | 403.0 | 69% | 123.9 |
| Channel Erosion | 41.0 | 71.8 | 0% | 71.8 | 73% | 19.2 | 69% | 22.1 |
| Point Sources | 0.4 | 0.9 | | 0.9 | | 0.9 | | 0.9 |
| Total | 2,522.5 | 7,379.8 | | 2,270.2 | | 2,270.2 | | 2,270.2 |

These three scenarios are defined as follows:

1. TMDL Alternative 1 takes all of the reductions from the largest source category - Agriculture.
2. TMDL Alternative 2 takes equal % reductions from all source categories, except Forestry and Point Sources.
3. TMDL Alternative 3 takes equal % reductions from all source categories, except Point Sources.

A concurrent bacteria TMDL for Mill Creek (Benham et al., 2006) requires an increased level of Livestock Exclusion from streams that directly affects the sediment loads from channel erosion in Mill Creek. A coordinated effort to restore the riparian vegetation in conjunction with Livestock Exclusion from localized, targeted stream sections should be a major step in remedying the fairly minor benthic impairment in the Mill Creek watershed.

7.1.5. Summary of TMDL Allocation Scenario for Sediment

The sediment TMDL for Mill Creek is 2,522.5 t/yr, but the modeling target is the TMDL minus the MOS (2,270.2 t/yr) and will require an overall reduction of

69% from existing loads. From the three alternative scenarios explored, Alternative 2 is recommended as the most reasonable approach as it requires equal % reductions from all categories except forestry which already produces very low unit-area loads and Point Sources which are permitted.

The Mill Creek sediment TMDL was developed to meet the sediment load of the area-adjusted TMDL reference watershed - upper Mill Creek above station MIL005.67. The TMDL was developed to take into account all sediment sources in the watershed from both point and nonpoint sources. The sediment loads were averaged over an 8-year period to take into account both wet and dry periods in the hydrologic cycle, and the model inputs took into consideration seasonal variations and critical conditions related to sediment loading. An explicit 10% margin of safety was added into the final TMDL load calculation.

CHAPTER 8: TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

8.1. TMDL Implementation Process

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairment on Mill Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 7.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR '122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at <http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf>. With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

8.2. Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement. Additionally, in agricultural areas of the Mill Creek watershed, the most promising best management practice to address the concurrent bacteria TMDL is livestock exclusion from streams. This practice is not only effective in lowering bacteria concentrations in streams, but will also have the mutually beneficial result of reducing soil detachment in the riparian corridor. Another important practice will be re-vegetation of bare sections of the riparian corridor. The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

8.3. Link to ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. The BMPs required for the implementation of the sediment allocations in this

watershed contributes directly to the sediment reduction goals set as part of the Chesapeake Bay restoration effort. Several BMPs known to be effective in controlling sediment have also been identified for implementation as part of the Commonwealth of Virginia Shenandoah and Potomac River Basins Tributary Strategy. For example, stream protection and riparian grass and forest buffers are among the components of the strategy described under nonpoint source implementation mechanisms. (VASNR, 2005). Up-to-date information on the tributary strategy implementation process can be found at the Virginia tributary strategy web site under the Shenandoah-Potomac Tributary Strategy link : <http://www.snr.state.va.us/WaterQuality/index.cfm>.

8.4. Reasonable Assurance for Implementation

8.4.1. Follow-up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever

possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants (“water quality milestones” as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ’s standard monitoring plan. Ancillary monitoring by citizens’ or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens’ monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at <http://www.deq.virginia.gov/cmonitor/>.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or

Implementation plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

8.4.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated

in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) which are both covered by NPDES permits and expected to be included in TMDL implementation plans, as described in the stormwater permit section below.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the state's Water Quality Management Plans. The WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning

are described in the public participation guidelines referenced above and can be found on DEQ's web site under <http://www.deq.state.va.us/tmdl/pdf/ppp.pdf>.

8.4.3. Stormwater Permits

DEQ and DCR coordinate separate State programs that regulate the management of pollutants carried by storm water runoff. DEQ regulates storm water discharges associated with "industrial activities", while DCR regulates storm water discharges from construction sites, and from municipal separate storm sewer systems (MS4s).

EPA approved DCR's VPDES storm water program on December 30, 2004. DCR's regulations became effective on January 29, 2005. DEQ is no longer the regulatory agency responsible for administration and enforcement of the VPDES MS4 and construction storm water permitting programs. More information is available on DCR's web site through the following link: <http://www.dcr.virginia.gov/sw/vsmp>

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is DCR's Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when:...(2) Numeric effluent limitations are infeasible,...".

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation.

However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. Any changes to the TMDL resulting from water quality standards changes on Mill Creek would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. An implementation plan will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Phase 2 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at <http://www.dcr.virginia.gov/sw/vsmp.htm>.

8.4.4. Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

8.4.5. Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, the current designated use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of the contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at <http://www.deq.virginia.gov/wqs/WQS03AUG.pdf>.

CHAPTER 9: PUBLIC PARTICIPATION

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made.

The first public meeting was held on May 18, 2005 at St. Andrews Episcopal Church in Mt. Jackson, Virginia to inform the stakeholders of the TMDL development process. Copies of the presentation materials were available for public distribution at the meeting. Approximately 20 people attended the meeting.

Two meetings of the Mill Creek Local Steering Committee (LSC) were held to assist with TMDL development. The first LSC meeting was held on November 9, 2005 at the Mt. Jackson Visitor Center/Town Office in Mt. Jackson, Virginia where the results of the benthic stressor analysis were presented and discussed. The second LSC meeting was held on February 21, 2006 at the Edinburg Town Hall in Edinburg, Virginia and addressed issues related both to the benthic impairment for Mill Creek described in this report and to a bacteria impairment in Mill Creek and surrounding portions of the North Fork Shenandoah River which are described in a separate report. The draft report from the benthic TMDL study was presented and discussed. Approximately 12 people attended the first LSC meeting.

The final public meeting will be held on March 21, 2006 at the Shenandoah County Parks and Recreation Office in Edinburg, Virginia. The public comment period will end on April 20, 2006. A summary of the questions received during the comment period and responses to the comments are available from the VADEQ Valley Regional Office in Harrisonburg, Virginia.

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Glossary of Terms

Allocation

That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario

A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels

Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

Best Management Practices (BMP)

Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Calibration

The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Direct nonpoint sources

Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: direct deposits of fecal material to streams from livestock and wildlife.

E-911 digital data

Emergency response database prepared by the county that contains graphical data on road centerlines and buildings. The database contains approximate outlines of buildings, including dwellings and poultry houses.

Hydrology

The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Load allocation (LA)

The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)

A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Model

Mathematical representation of hydrologic and water quality processes. Effects of Land use, slope, soil characteristics, and management practices are included.

Nonpoint source

Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Point source

Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution

Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach

Segment of a stream or river.

Runoff

That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Simulation

The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Total Maximum Daily Load (TMDL)

The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff

Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)

Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload allocation (WLA)

The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard

Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed

A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

For more definitions, see the Virginia Cooperative Extension publications available online:

Glossary of Water-Related Terms. Publication 442-758.

<http://www.ext.vt.edu/pubs/bse/442-758/442-758.html>

and

TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Publication 442-550.

<http://www.ext.vt.edu/pubs/bse/442-550/442-550.html>